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LAGOON TREATMENT AND CONVEYANCE SYSTEMS SOUTHEASTERN MICHIGAN W--ETC(U)

NOV 72 DACW35-72-C-0034

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SECTION I

GENERAL

GENERAL

Purpose

The Detroit District of the U. S. Army Corps of Engineers (CORPS) is performing a survey-scope study to define, evaluate and select an optimum regional wastewater management system for Southeastern Michigan. The purpose of the Lagoon Treatment and Conveyance Systems Study is to develop preliminary designs for lagoon treatment systems and for conveyance systems for two representative land wastewater treatment facilities. The CORPS will make use of the result of this study and of other studies, including an Irrigation and Collection Facilities Study and an Advanced Wastewater Treatment Plant Study, to determine the optimum wastewater management system.

Scope

The system components covered in this study include the equalization lagoons, screening and grit chambers, aerated lagoons and chlorination facilities that are used to treat the wastewater prior to irrigation. Also covered are the conveyance systems, consisting of force mains, gravity flow interceptors, or deep tunnels, and the associated pumping stations which are necessary for transport of the wastewater to the treatment sites and to the irrigation sites and ultimate disposal sites. Conveyance systems were designed and the costs estimated for use →

next page

cont

with the advanced wastewater treatment plant alternatives as well as the land treatment alternatives.

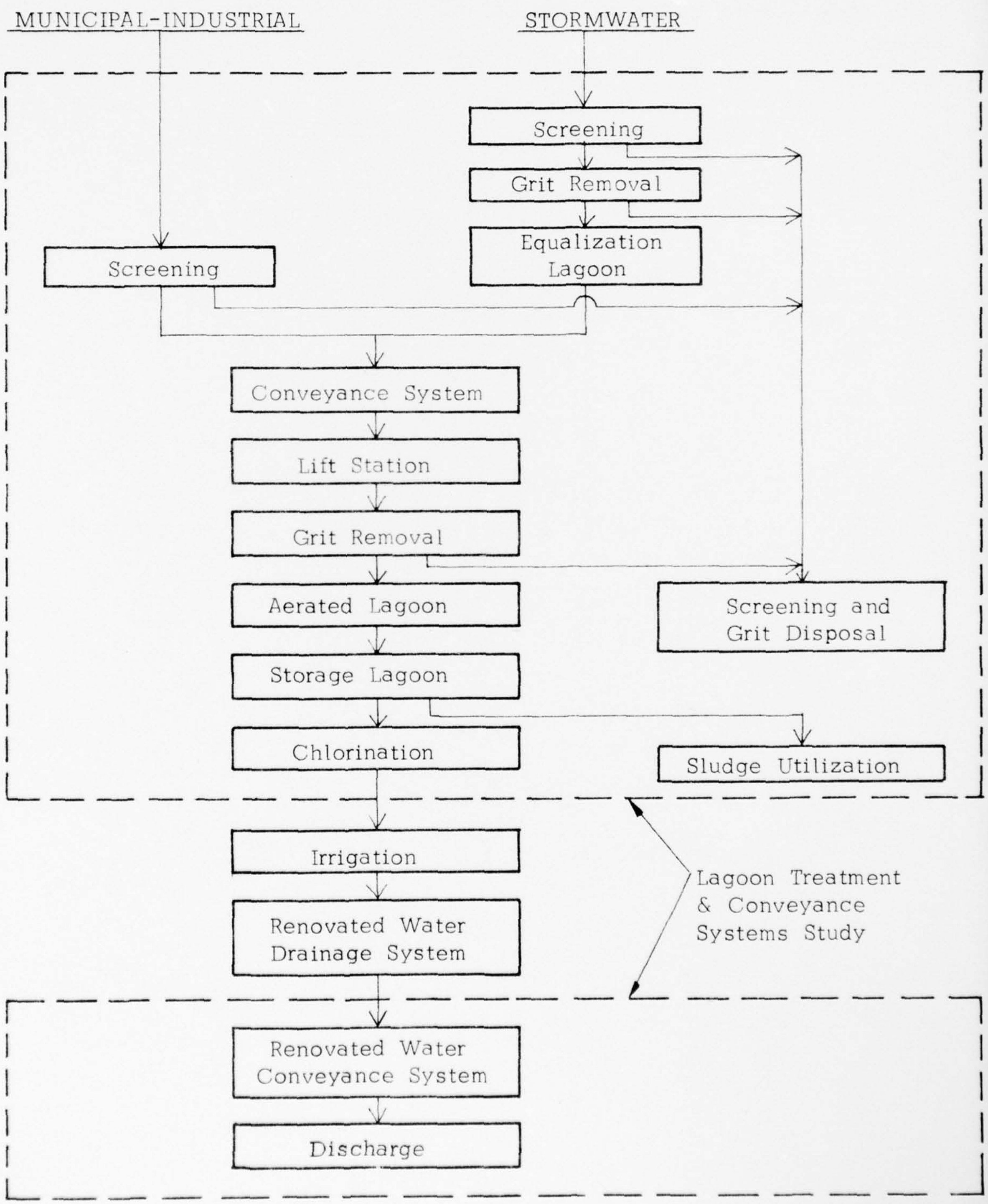
Introduction to Land Treatment

The land treatment of wastewater makes use of the natural capability of the soils "Living Filter" to remove contaminants from water. The facilities described here are part of a management system to treat the municipal and industrial wastewater and stormwater for the Southeastern Michigan area. The components of the land treatment systems are shown in Figure I-1. Municipal and industrial wastewaters are screened and the grit is settled out prior to entering the aerated lagoons. Stormwater enters the aerated lagoons at a constant rate after flowing through equalization basins. In the aerated lagoons biological activity results in stabilization of 70 to 90% of the biochemical oxygen demand. The effluent is discharged to storage lagoons where the sludge settles out and the water, now comparable in quality to effluent from a secondary treatment plant, is stored during freezing and wet periods.

The water from the storage lagoons is disinfected by chlorination and used to irrigate crops. The biological, chemical and physical characteristics of the soil are utilized to treat the wastewater. This step is the "Living Filter". A drainage system collects the water and directs it to the disposal site, which can be local streams, the St. Clair River, or Lake Erie. The irrigation and drainage design is not included in this report.

FIGURE I-1

FLOW DIAGRAM OF TYPICAL LAND TREATMENT SYSTEM



Each of the components of the conveyance and lagoon treatment systems is described in this report, and design bases and estimated costs are presented.

SECTION II

METHODOLOGY

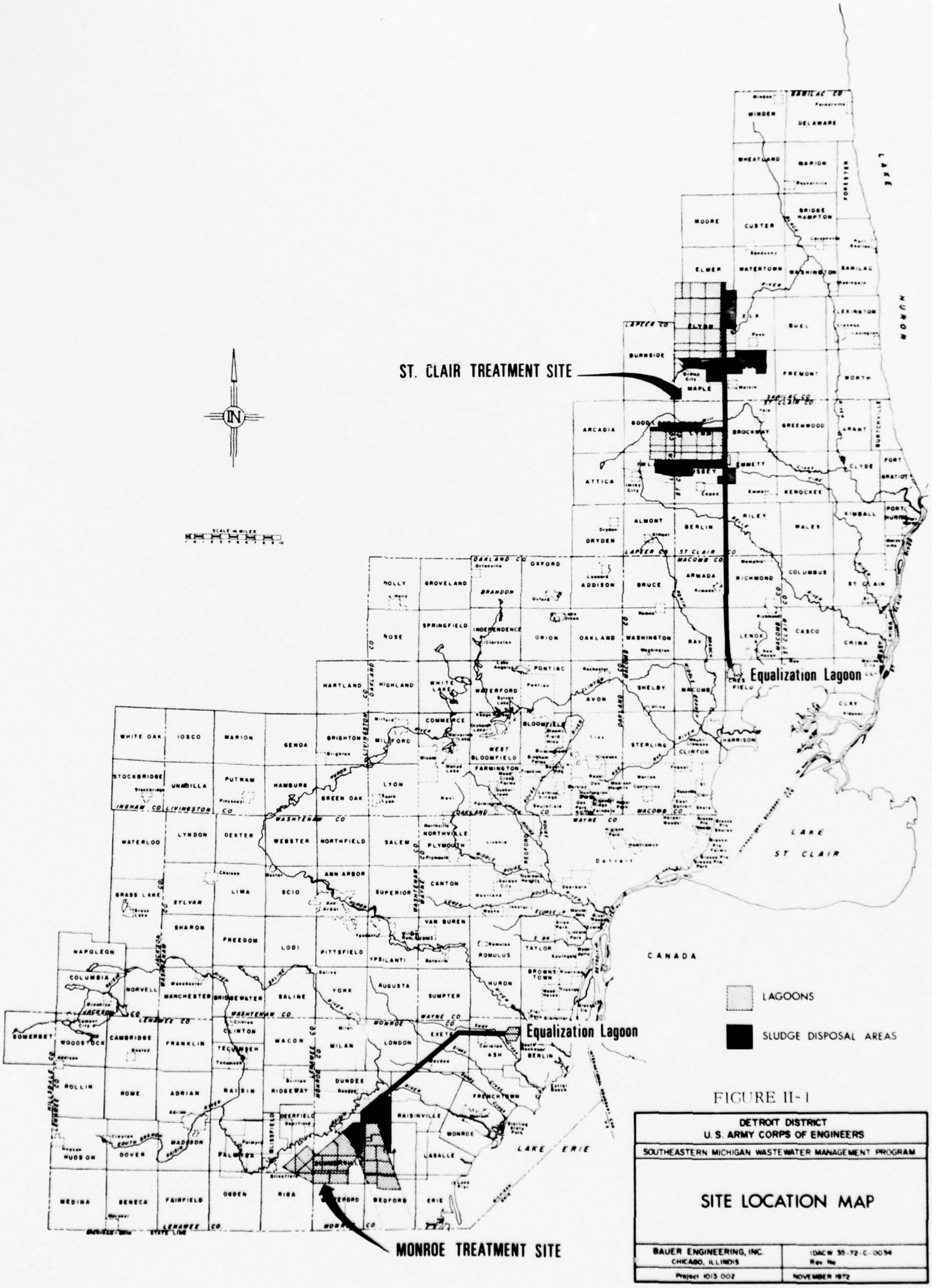
METHODOLOGY

The design of components of the lagoon treatment and conveyance systems was accomplished using basic input data that was supplied by the CORPS. The locations of the lagoon treatment facilities, the equalization lagoons, and the conveyance corridors chosen by the CORPS for design are shown in Figure II-1.

The northerly lagoon treatment site referred to as the St. Clair Treatment Site is located in St. Clair and Sanilac Counties, and is centered about 54 miles north of Detroit. The lagoons and sludge disposal areas comprise an area of approximately 150 square miles, and are shown in Figure II-2.

The second lagoon treatment site, the Monroe Treatment Site, is located in Monroe County, about 44 miles southwest of Detroit. This site encompasses approximately 75 square miles, and is shown on Figure II-3. Both sites are designed to treat wastewater from industrial, municipal and stormwater sources prior to its distribution to irrigation areas for treatment by the "Living filter" of the soil.

The CORPS provided the design flow rates for each site and the municipal-industrial and stormwater constituents as shown in Table II-1 and II-2. The combined flow rates and constituent loadings shown in the tables were calculated and used as a basis of design for the conveyance and lagoon treatment systems, except as discussed elsewhere.



ST. CLAIR TREATMENT SITE
Equalization Lagoon
Equalization Lagoon
MONROE TREATMENT SITE
LAKE HURON
LAKE ST CLAIR
LAKE ERIE
CANADA
LAGOONS
SLUDGE DISPOSAL AREAS
DETROIT DISTRICT
U.S. ARMY CORPS OF ENGINEERS
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM
SITE LOCATION MAP
BAUER ENGINEERING, INC.
CHICAGO, ILLINOIS
DACW 35-72-C-0034
Rev. No.
Project 1013.002
NOVEMBER 1972

FIGURE II-1

Design by	Date	Checked by	Date	Drawn by	Date	Checked by	Date	Revised by	Date	Checked by	Date

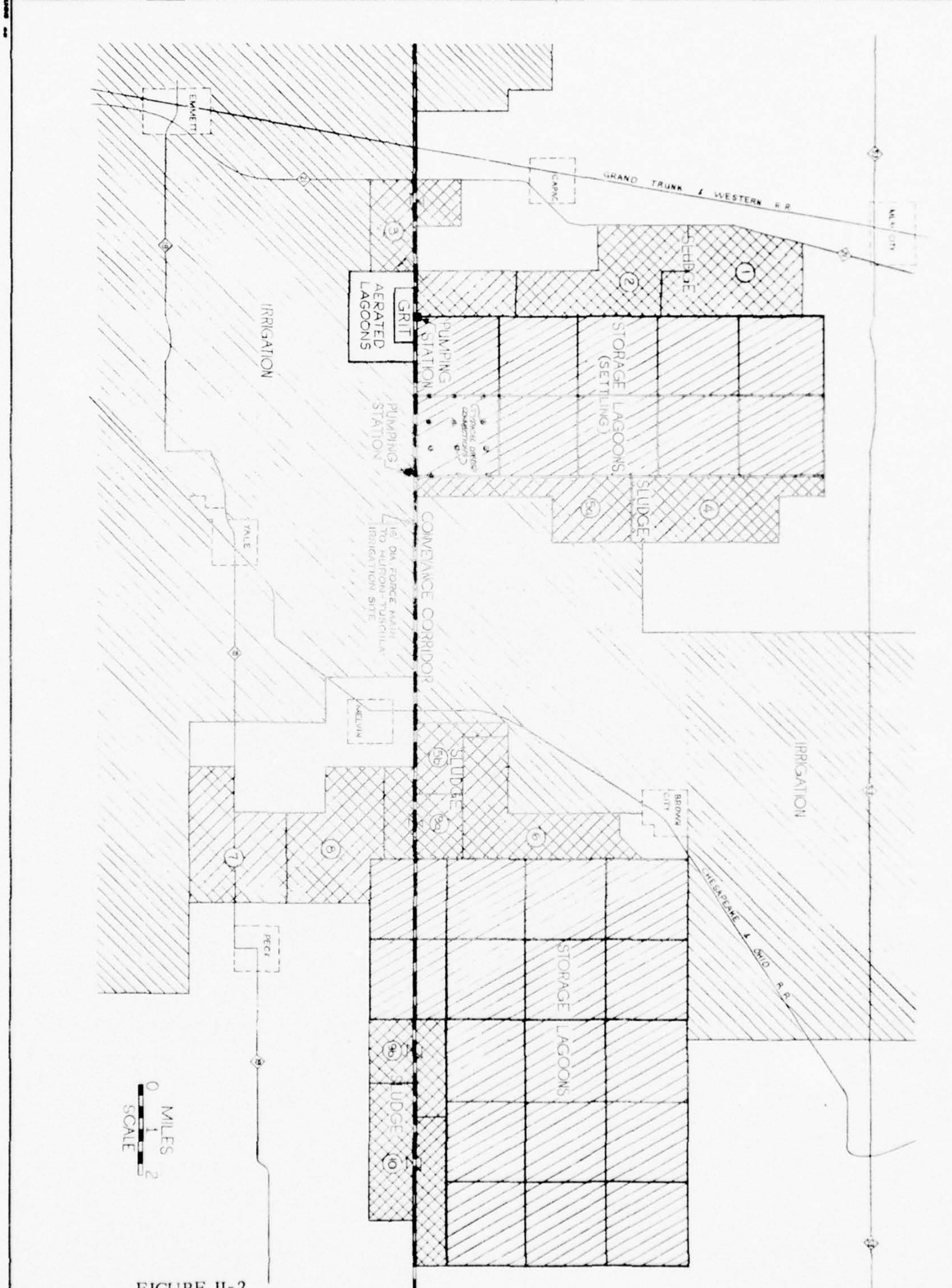


FIGURE II-2

DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

LAGOON TREATMENT FACILITIES
ST.CLAIR LAND TREATMENT SITE

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Project 1013.002	NOVEMBER 1972 SHEET OF

Design by	Date	Checked by	Date	Drawn by	Date	Checked by	Date	Revised by	Date	Checked by	Date

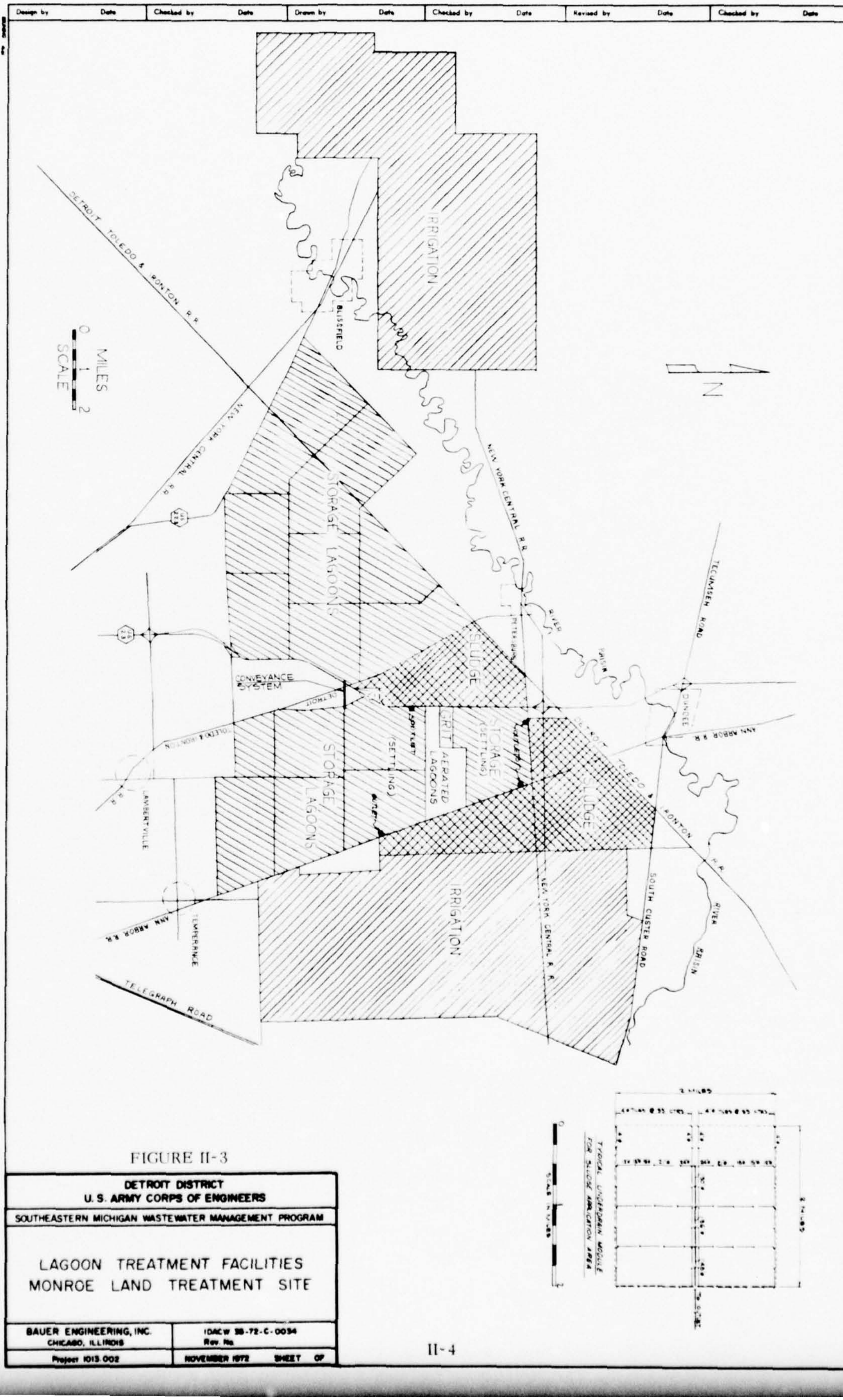

FIGURE II-3

DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

LAGOON TREATMENT FACILITIES
MONROE LAND TREATMENT SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No.
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TABLE II-1

DESIGN FLOW RATES, MGD

Treatment Site	Municipal and Industrial Avg. Daily	Peak*	Stormwater Average Annual	Combined Average	Peak	Renovated Average
St. Clair	1130	1978	1055	2185	3033	2148
Monroe	320	560	1055	1375	1615	665

* Flow calculated with peaking factor of 1.75

TABLE II-2

PROFILE OF WASTEWATER CONSTITUENTS

Constituent	Municipal and Industrial mg/l	Stormwater mg/l	St. Clair Site Combined mg/l	Monroe Site Combined mg/l
BOD	132	40	88	61
COD	350	100	230	157
Suspended Solids	226	300	261	283
Settleable Solids	129	75	103	88
Volatile Solids	158	120	140	128
PO_4	36	7.5	23	14
Oils & Greases	71	25	49	35
NH_3 - N	7.5	4.5	6	6
NO_3 - N	0.051	1	0.53	1.01

The design of the sludge management system is based on a value of 0.8 tons of solids generated per million gallons of industrial-municipal wastewater treated. This is a typical value used for a large metropolitan area. The constituent loadings of stormwater as shown in Table II-2 are values that appear to be more representative of those obtained during the first flushing portion of a storm flow than that of the average value for stormwater runoff.

Design Methodology

The report is organized into sections relating to each major component. This section contains a brief explanation of the methodologies that were used to design each of the components.

Conveyance Systems

Eighteen conveyance systems were designed at the request of the CORPS. The systems include gravity interceptors, force mains, and deep tunnels. Two systems convey wastewater from the equalization lagoons to the land treatment sites, two systems convey renovated water from the land treatment sites to the discharge points, three systems convey water from the lagoon treatment systems to isolated irrigation sites, and the other eleven systems convey wastewater to advanced wastewater treatment plants and/or land treatment sites.

The average daily flow for each of the conveyance systems was supplied by the CORPS. To obtain the peak daily flow upon which most of the conveyance systems were sized, the average daily flow for the system was multiplied by a peaking factor of 1.75. This factor was developed from analyses made by Bauer Engineering, Inc. in the Chicago Area for the Chicago District, U. S. Corps of Engineers. It was concluded that the Chicago and Detroit sanitary sewer system designs were based on similar criteria and, therefore, the flow characteristics are similar.

An equalized stormwater flow is included in the total flow for the two conveyance systems from the equalization lagoons to the land treatment sites. The drainage area was provided by the CORPS and a continuous, year around, pump out rate was specified. The design flows for these two conveyance systems is simply the sum of the peak daily municipal-industrial flow and the equalized stormwater flow.

The renovated water design flow was as specified by the CORPS as shown in Table II-1. No peaking factor was used for either the renovated water flow or the three lines from the lagoon treatment sites to the isolated irrigation sites.

Each of the conveyance systems was optimized by calculating the transmission line and pump station annual costs for several sizes of transmission line and determining the lowest cost overall system. The designs take into account the restrictions imposed by the topography and geology of the area.

Equalization Lagoons

Each of the land treatment systems contains two equalization lagoons to store stormwater flows during periods of heavy runoff. These lagoons are included in the system to receive runoff from the urban areas to be treated without requiring excessive capacities for the conveyance and treatment systems.

The lagoons for each treatment system are designed to contain 2.1 inches of runoff over an area of 400 square miles. Two lagoons are included at each site, each with half the total storage capacity. Pump out from the lagoons will be at a constant, year-around rate.

Screening and Grit Removal Facilities

Screening and grit removal are included in the systems for land treatment. Automatically cleaned screens are located immediately ahead of the tunnels to eliminate unnecessary trash from entering the system. The debris collected at the screens will be transported by truck to the landfill.

The grit chambers and removal equipment are located on the surface near the shaft at the discharge end of the conveyance system. The chambers are designed to settle out the larger, inert solids while settling a minimum of organic matter. Grit will be disposed of on a sanitary landfill.

Aerated Lagoons

The aerated lagoons are designed to provide sufficient oxygen and adequate mixing to stabilize 70 to 90% of the BOD_5 in the wastewater. The lined lagoons are designed as modules with individual capacities of 80 MGD. Thirty-six large floating surface aerators in each cell provide the mixing and oxygenation energy. The BOD remaining after aeration can be accommodated in the storage lagoons without exceeding loading limits of the Ten States Standards for oxidation ponds, and thus minimizing the potential for odor generation.

Each lagoon has a 15 foot working depth, a 5 foot freeboard, side slopes of 4:1, and covers an area of 57 acres. The interior slopes are provided with concrete wave protection to a depth of 10 feet; soil cement continues from the 10 foot depth to the toe of the slope. A clay lining covers the bottom of the lagoons with soil cement pads under each aerator.

Storage Lagoons

Several processes occur in the storage lagoons. The partially treated wastewater from the aerated lagoons enters the adjacent storage lagoons, which act as settling basins. During the winter months and periods of heavy rainfall, the lagoons serve their primary function of storage of the wastewater until it can be used for irrigation. An additional process continually taking place in the storage lagoons during ice-free periods is the stabilization of the remaining BOD by natural surface aeration and photosynthetic activity.

The storage lagoons are designed in modules of approximately 3 square miles each. This allows for a flow of 80 MGD and 155 days storage and a total capacity of 12.4 billion gallons. A storage period of 155 days has been determined as necessary to avoid having to irrigate when the ground is frozen or excessively wet.

The size of the storage lagoon module was selected as large enough to take advantage of the economies of scale while being small enough to fit into the existing geography without excessive modifications. A dike height of 30 feet was selected as the most economical height when comparing land cost to dike construction cost. A maximum water depth of 23 feet, including 3 feet of dead storage, allows for a 7 foot freeboard. The dike sides, with a 4:1 slope, are stabilized with soil cement to prevent erosion. A service road of 20 feet is constructed around the perimeter of each unit. Seepage control from the lagoons is discussed separately later in this report.

The chlorination facilities for disinfection of the wastewater prior to spray irrigation are constructed as a part of the storage lagoons. Chlorination takes place at the outlet of the lagoons and is designed to achieve a coliform bacteria count of 1,000 or less per 100 ml. The required chlorine contact time and dechlorination time are assumed to be accommodated in the open channels leading to the irrigation distribution system.

Seepage Control

It is important that wastewater from the lagoons be isolated from the surrounding groundwater to avoid saturation of the irrigation areas and contamination of nearby water supplies.

Seepage from the lagoons is effectively controlled by a combination of relatively impermeable linings, intercepting ditches, and wells. The aerated lagoons are lined with clay. The storage lagoon sites have a minimum of a 400 foot wide clay lining around their perimeters. Drainage ditches around the lagoon sites intercept any water that does seep through the soil and pumping stations in the ditches pump the seepage back into the lagoons.

The performance of the storage lagoon seepage control system will be continuously monitored to assure protection of the groundwater supply near the treatment site. The monitoring system consists of observation wells around the perimeter of the lagoon site. The wells are placed at 2,000-foot intervals in three-well clusters to monitor both horizontal and vertical migration at the top, midpoint, and bottom of the groundwater aquifer.

Movement of groundwater through soil is generally very slow. Thus, if changes are detected in the groundwater, there is sufficient time to analyze and correct the problem. Placement of temporary well points or drainage wells could be installed if desired.

Sludge Management

Sludge generated as a by-product of wastewater treatment is disposed of by application to the land for the purpose of increasing the humus content and fertility of the receiving soil. This biologically produced sludge is first stabilized in the storage lagoons.

Sludge is generated predominately from the municipal and industrial flow of each system. This sludge accumulation may reach a concentration of 10 to 12%. However, it is anticipated that during normal dredging operations concentration will be reduced to about 6% by weight of total solids. The sludge will be pumped through pipelines and booster pumps to the distribution system.

Sludge will be applied to the land with the use of the roll-over plow which moves at a constant rate of speed and applies sludge uniformly to the land. Sludge is transported through portable pipelines and flexibile hoses to each plow. One pass is made over the land each year.

The sludge is applied at a rate of 10 dry tons per acre per year. This rate makes optimum use of the land and crops for removal of nutrients from the sludge. The critical nutrient is nitrogen. The sludge is assumed to contain 3% nitrogen on a dry basis. This sludge application rate results in a nitrogen load of 600 pounds per acre per year. One-third of this, or 200 pounds per acre is in the ammonia form and available im-

mediately for use by crops. The other 400 pounds per acre of nitrogen is in the organic form and is released at about 3% a year. University of Illinois experience with agricultural sludge indicates that 240 to 260 pounds of nitrogen of each yearly application can be expected to be unavailable to the crop because of volatilization and other losses. The remaining nitrogen available for crop utilization is 340 to 360 pounds per acre per year. Frequent cutting and removal is to be practiced for the typical grass crops.

Cost Estimation Methodology

The cost of the major components of each system and total system costs are estimated for the recommended designs. The costs are based upon the prevailing prices on January 1, 1972. Many construction costs are based upon bids received for a land wastewater treatment system at Muskegon, Michigan in May, 1971. Other costs are developed from the Cost Data Annex to the Technical Appendix for the Regional Wastewater Management System for the Chicago Metropolitan Area, prepared for the U.S. Army Corps of Engineers - Chicago District. The estimated costs are adjusted to an ENR Construction Cost Index of 1960, an EPA Sewage Treatment Plant Cost Index of 180.73, or an EPA Sewer Construction Cost Index of 200.77.

Capital costs include construction costs, land costs, engineering (10% of construction), administrative (5% of construction) and contingencies (10% of construction). The annual capital costs are calculated using capital recovery factors at interest rates of 5-1/2, 7 and 10%. The operating and maintenance costs

include power (at \$.01/KWH), labor (including 25% overhead) and materials and supplies. The replacement costs are determined for those major equipment items that cannot be replaced by the normal labor force during regular maintenance. To annualize the replacement costs, the present worth is first calculated for all items and then the capital recovery factor is used for the total present worth to obtain the annual replacement cost. Interest rates of 5-1/2, 7 and 10% are used, the same interest rate being used to determine present worth as is used for the respective capital recovery factor.

The total annual costs at 5-1/2, 7 and 10% interest are the sums of the annual capital costs, annual operating maintenance costs and annual replacement costs.

The costs of minor construction items are included with their associated major items whenever they are not specifically listed in the summaries. For example, the downshaft costs are included as part of constructing the deep tunnels.

Lagoon Treatment System Performance

The interface between the lagoon treatment system and the irrigation system is important in this study because the two systems are being designed by different contractors. The quality of the wastewater entering the irrigation system is a parameter in the irrigation system design, and therefore an estimate of the lagoon treatment system performance is included here for use as desired by the CORPS.

Constituents of the lagoon treatment system effluent are shown in Table II-3. These are estimated values of the effluent as it leaves the storage lagoons. The values are based on the influent wastewater constituent profiles shown in Table II-2 which are specific for the Detroit area, or the normally limiting values of constituent removal for secondary biological treatment. The values are typical of what can be expected in the storage lagoon effluent, even with normal variation in the influent concentrations.

TABLE II-3

CONSTITUENTS OF LAGOON TREATMENT SYSTEM EFFLUENT

Constituent	St. Clair Site (mg/l)	Monroe Site (mg/l)
BOD	20	20
COD	60	60
Suspended Solids	25	25
PO_4	18	11
Oils and Greases	10	10
NH_3-N	7	7
NO_3-N	.4	.4
Pathogens, Viruses	Present, coliform bacteria less than 1,000 per 100 ml	

SECTION III

DESIGN OF LAGOON TREATMENT SYSTEMS

DESIGN OF LAGOON TREATMENT SYSTEMS

The lagoon treatment systems designed in this section are those shown in Figure II-1 and designated as the St. Clair Treatment System (Figure II-2) and the Monroe Treatment System (Figure II-3). The components included within the systems are the following.

- Equalization Lagoons
- Wastewater Conveyance Facilities
- Screening and Grit Removal Facilities
- Aerated Lagoons
- Storage Lagoons
- Seepage Control Systems
- Sludge Management Systems
- Renovated Water Conveyance Facilities

A brief discussion of the time phasing for constructing and operating each of the components is included at the end of this section.

Equalization Lagoons

Each of the land treatment systems contains equalization lagoons to store stormwater flows during periods of heavy runoff. The lagoons are included in the system to enable the storm runoff in the urban areas to be treated without requiring excessive capacities for the conveyance and treatment systems.

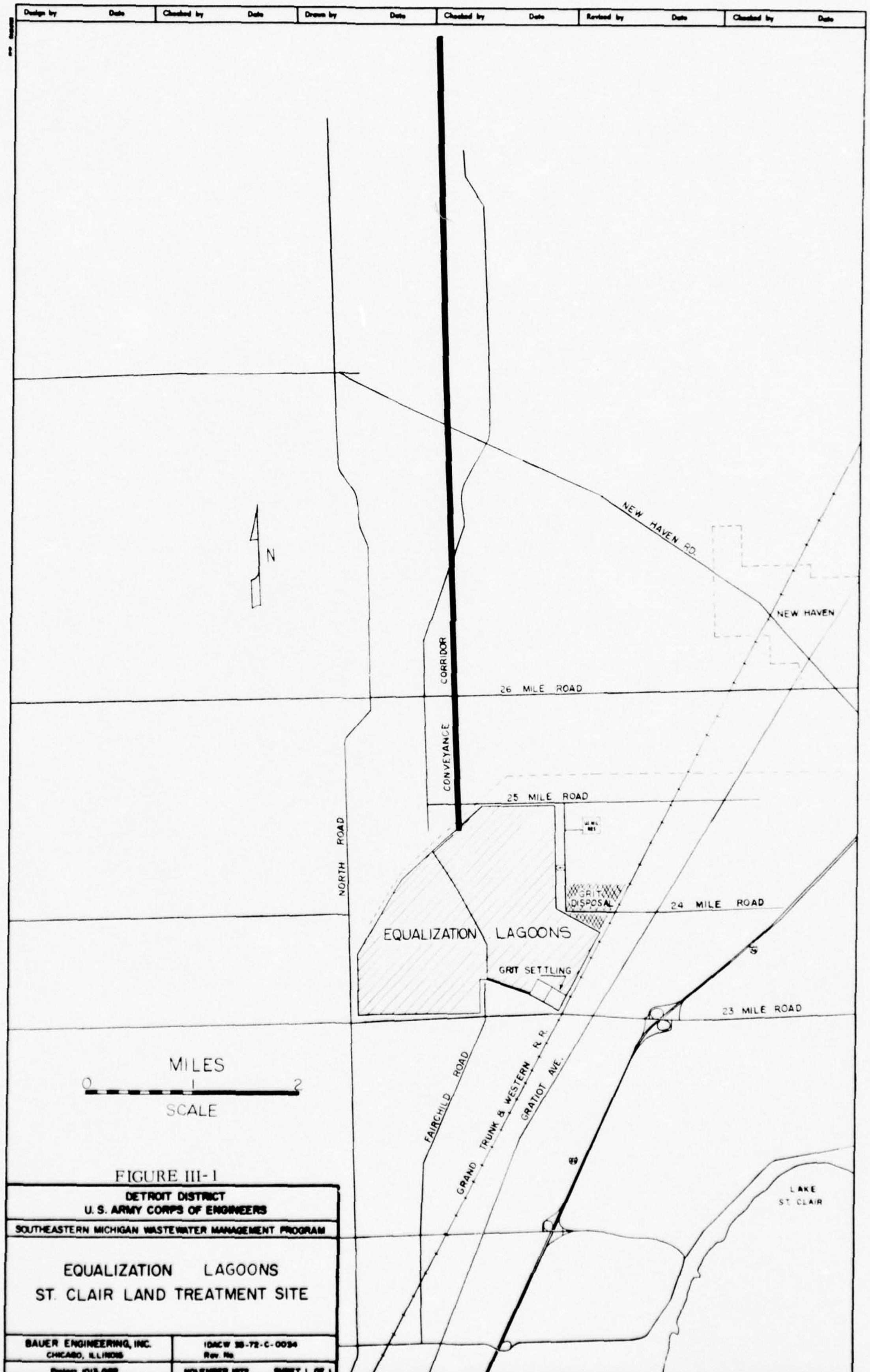
Design Criteria

The equalization lagoon for the St. Clair Site will be located in Macomb County between 23 and 25 Mile Roads, and North Road and the Grand Trunk and Western Railroad tracks, as shown on Figure III-1.

The Monroe Site equalization lagoons will be located between Siegler and Carleton-Rockwood Roads and Telegraph and Armstrong Roads in Monroe County. Figure III-2 shows the plan of these lagoons.

There will be two lagoons at each location, with a capacity of 7,308 million gallons per lagoon. The lagoons are designed to contain 2.1 inches of runoff from drainage areas of 400 square miles.

Figure III-3 shows the typical equalization lagoon in cross-section. The dikes will be 30 feet high and will provide a maximum 23 foot working depth of water with a 7 foot freeboard. There will be an 8 inch layer of soil cement on the 1 on 4 in-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N
NEW HAVEN RD.
NEW HAVEN
CONVEYANCE CORRIDOR
26 MILE ROAD
25 MILE ROAD
NORTH ROAD
GRIT DISPOSAL
24 MILE ROAD
EQUALIZATION LAGOONS
GRIT SETTLING
23 MILE ROAD
MILES
0
1
2
SCALE
FAIRCHILD ROAD
GRAND TRUNK & WESTERN R.R.
GRATIOT AVE.
LAKE
ST. CLAIR
DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM
EQUALIZATION LAGOONS
ST. CLAIR LAND TREATMENT SITE
BAUER ENGINEERING, INC.
CHICAGO, ILLINOIS
Rev. No.
NOVEMBER 1972
SHEET 1 OF 1

FIGURE III-1

Design by	Date	Checked by	Date	Drawn by	Date	Checked by	Date	Revised by	Date	Checked by	Date

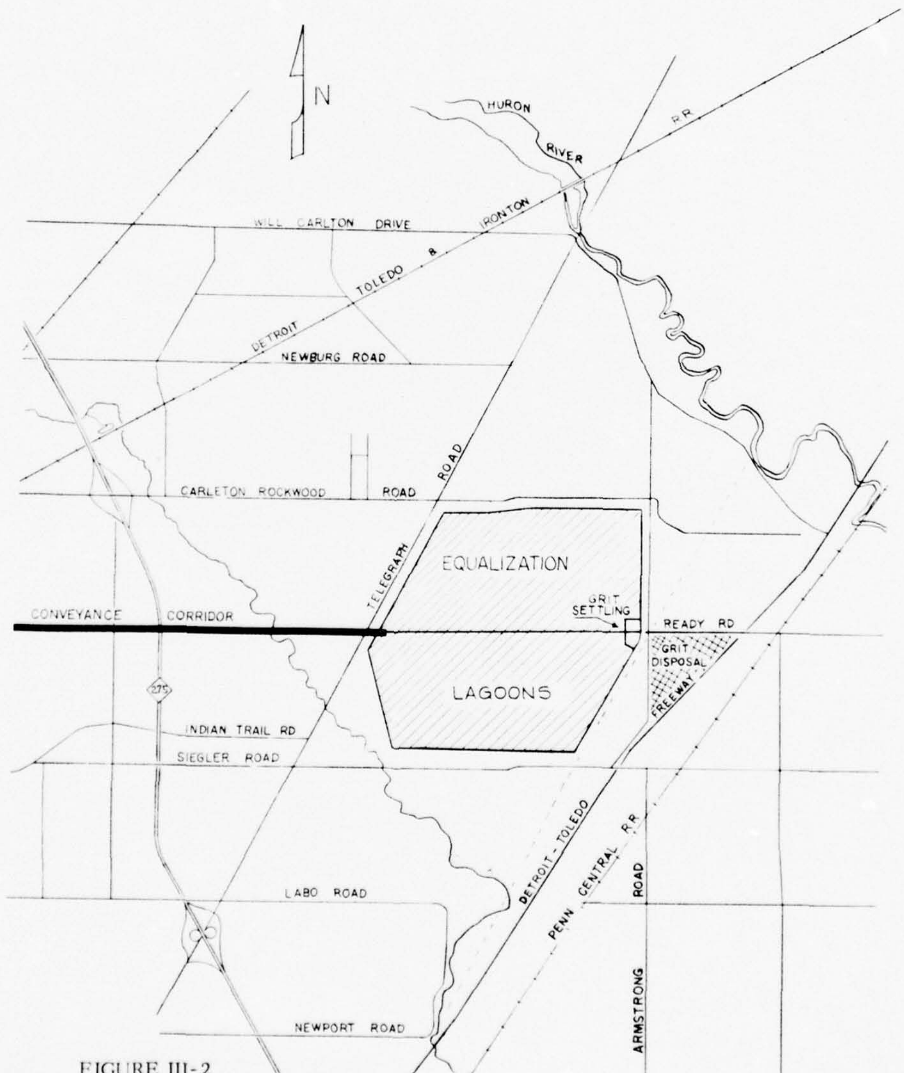

FIGURE III-2

DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EQUALIZATION LAGOONS
MONROE LAND TREATMENT SITE

BAUER ENGINEERING, INC.
CHICAGO, ILLINOIS

Project 1013 002

DACW 35-72-C-0034
Rev. No.

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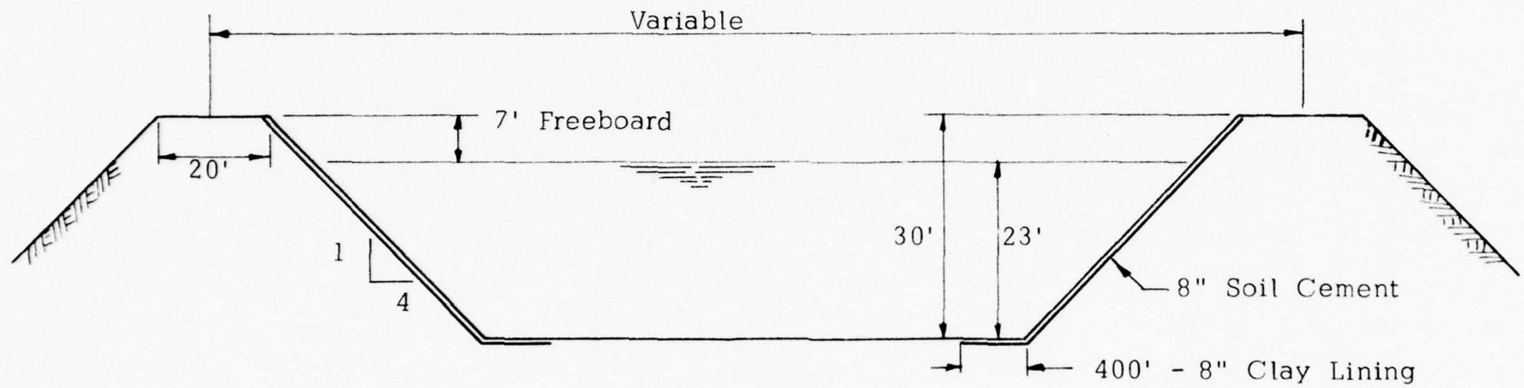
MILES
0 1 2
SCALE

FIGURE III-3
TYPICAL EQUALIZATION LAGOON
CROSS-SECTION



terior side slopes for wave protection and a 400 foot wide clay lining 8 inches thick from the toe of the slope extending toward the center of the lagoon for seepage control. This design is based upon criteria similar to the storage lagoons in which dike height vs. cost was optimized. Details of the design criteria are provided in Table III-1.

Only grit settling will be accomplished at the equalization lagoons. Organic material will pass through the lagoons to the treatment sites. The discharge rate to the conveyance system from the lagoons is constant at 1,055 MGD.

Alternatives

The alternative to an equalization lagoon system is to design the conveyance and aerated lagoon systems to include the maximum runoff flow. This is a much higher cost system than if the equalization lagoons are included, and was not considered here.

Costs

A summary of the costs associated with the equalization lagoons is shown in Table III-2. A more detailed list including unit prices is included in the Appendix.

Performance and Reliability

The two-cell design of the equalization lagoons will provide for reliability and flexibility when maintenance is required on the units.

Table III-1

EQUALIZATION LAGOON DESIGN DATA

	St. Clair	Monroe
Number of Lagoons	2	2
Volume/Lagoon-MG	7,308	7,308
Volume/Lagoon-Acre-Feet	22,400	22,400
Water Depth-Feet	23	23
Freeboard-Feet	7	7
Dike Height-Feet	30	30
Land Area/Lagoon-Acres	1,000	1,000
Total Land Area-Acres	2,000	2,000
Total Land Area-Square Mile	3	3

Table III-2
COST SUMMARY FOR
EQUALIZATION LAGOONS

	St. Clair	Monroe
Capital Cost		
Earthwork	$5,778,000	$5,778,000
Slope Bottom and Roadway Construction	1,912,000	1,912,000
Flow Structure	176,000	176,000
Service Building	32,000	32,000
Subtotal	$7,898,000	$7,898,00
Land	6,000,000	4,000,000
Engineering - 10%	789,800	789,800
Administration - 5%	394,900	394,900
Contingency - 10%	789,800	789,900
TOTAL	$15,872,500	$13,872,500
Operations and Maintenance/yr.		
Labor (includes 25% overhead)	$ 113,000	$ 113,000
Material & Supplies (0.1% of Capital Cost)	8,000	8,000
TOTAL	$ 121,000	$ 121,000

WASTEWATER CONVEYANCE SYSTEM

The transmission of wastewater from the equalization lagoons to the lagoon treatment sites is included as a part of the lagoon treatment system. For the large flows involved in this study, deep mole type tunnels designed for gravity flow are the best solution to this major conveyance problem. A single mole type tunnel from the equalization lagoons to the lagoon treatment site is used in both the St. Clair and Monroe land treatment systems. Wastewater from the equalization lagoons is transmitted through a vertical drop shaft to the mole type tunnel which is placed in a suitable rock strata for this type of tunnel construction. The wastewater flows through the tunnel until reaching the lagoon treatment site where it is pumped back to the surface and into the treatment system.

Design Criteria

Considerable work has been done on the design of deep or mole type tunnels for wastewater conveyance in conjunction with the Chicago-South End of Lake Michigan Wastewater Management Study (C-SELM) by the Chicago-District, U.S. Army Corps of Engineers. This experience is relied upon extensively in the design of the wastewater conveyances for this study. The deep or mole type tunnels for both the St. Clair and Monroe land treatment systems are sized on the basis of a combined wastewater flow made up of an equalized stormwater flow and a peak daily municipal-industrial flow. The

peak municipal-industrial flow is assumed to be 1.75 times the average daily flow.

The conveyance tunnels are designed with a circular cross-section and, by placement in the proper type of rock strata, the tunnels are smooth enough for use without an additional concrete lining. To insure that the proper rock strata is present, geological formations were plotted to assist in the vertical positioning of the tunnels.

Because of the smooth tunnel walls produced by the mole boring machine, these tunnels are sized using a value of $n = 0.017$ in Manning's formula. Sizing curves developed from the C-SELM report using this factor are given in the Appendix. To insure that solids will not settle out during transmission, a minimum velocity of 2.0 feet per second is maintained at all times within the systems.

Each system is provided with an underground pumping station at the discharge end of the tunnel to lift the wastewater back to the surface. The pumping station is sized for the same flow conditions used in sizing the tunnels and is provided with enough horsepower to lift the peak combined flow from the terminus of the tunnel to the aerated lagoons on the surface, a distance which varies for each of the systems.

Exhibit 1 gives the plan and profile of the St. Clair wastewater conveyance tunnel. The tunnel is located in the

Coldwater and Sunbury shales of the Mississipian formation, and follows a route due north beginning at the intersection of the 24 Mile Road and the Owo Road, and ending in Section 1, Mussey Township, St. Clair County, a distance of 25.3 miles. The pertinent design data for this conveyance system are listed in Table III-3.

Exhibit 2 shows the plan and profile of the Monroe wastewater conveyance tunnel. This tunnel is located in the Devonian and Silurian Dolomite formations. The starting point for this system is near U.S. 24-25 and Ready Road in Monroe County, and the tunnel extends west to and continues along the Detroit, Toledo, and Ironton Railroad right-of-way to U.S. 23. It then turns south, parallel to U.S. 23 and terminates in Section 13, Summerfield Township, a distance of 23.6 miles. The pertinent design data for this conveyance system are also listed in Table III-3.

Alternatives

For the extremely large wastewater flows involved in this conveyance system, alternatives to the deep tunnel system proposed are impractical economically as well as from an engineering viewpoint. Work done for the C-SELM study and for the flood and pollution control plan for the Chicago area have pointed out the specific merits of using this type of conveyance system.

Table III-3

WASTEWATER CONVEYANCE
SYSTEM DESIGN DATA

Location	St. Clair	Monroe
Exhibit No.	1	2
Total Length Miles	25.3	23.6
Type of Line	Tunnel	Tunnel
Diameter, Feet	23.0	18.0
Design Flow MGD	3,033.0	1,615.0
No. of Pump Stations	1	1
Pump H.P. Per Station	399,300	148,800
Tunnel Slope Ft/1000 Ft.	1.5	2

The final selection of a tunnel and pump station system is based on the economic analysis of several possible design alternatives. Each alternative consists of a specific tunnel diameter and slope and the associated pumping station. These possible combinations are compared by calculating the transmission tunnel and pump station annual costs for each possibility and selecting the design with lowest overall annual cost as optimal for the system. This method is used in sizing the tunnels and pump stations for both wastewater conveyance systems of this study.

Costs

Table III-4 gives the cost summaries for the wastewater conveyance systems required for both the St. Clair treatment system and the Monroe treatment system. Unit costs and more detailed cost information on these systems are included in the Appendix.

Performance and Reliability

By using gravity flow, the reliabilities of the wastewater conveyance systems are enhanced. The wastewater transmission tunnels are designed to maintain self-cleaning velocities and the equalization lagoons are sized to prevent surcharge of the tunnels during periods of high runoff. Both of these criteria will allow the wastewater conveyance systems to perform well at all flow conditions, and remove the need for any special tunnel cleaning procedure to be included in their operation.

Table III-4

COST SUMMARY FOR WASTEWATER CONVEYANCE SYSTEM

Capital Cost	St. Clair	Monroe
Tunnel	$ 87,397,000	$ 59,290,000
Pump Station	35,412,000	28,874,000
Subtotal	122,809,000	88,164,000
10% Engineering	12,281,000	8,816,000
5% Administration	6,140,500	4,408,000
10% Contingency	12,281,000	8,816,000
Total	$ 153,511,500	$ 110,204,000
Operation and Maintenance/Year		
Power	$ 18,793,000	$ 8,276,000
Labor (includes 25% overhead)	524,500	404,000
Materials & Supplies		
Pump Station	177,100	144,400
Tunnel	85,200	57,700
Total	$ 19,579,800	$ 8,882,100
Replacement Cost-Pump Station		
20% - 25 Years	$ 7,082,400	$ 5,774,800
15% - 10 Years	$ 5,311,800	$ 4,331,100

Pressurized tunnel systems would require safeguards against groundwater contamination by the wastewater during transmission that are not necessary in a gravity system. These safeguards along with additional mechanical requirements would increase both the capital and operational costs of the conveyance systems if pressure systems were used.

Pumping station performance is assured at all flow conditions with the proper selection of the number and sizes of the pumps. Reliability of the station is maintained with a regular program of maintenance and inspection.

It is essential that a redundant supply of electrical power be provided for the treatment systems, including the wastewater pumping stations. A standby power generation facility would be prohibitively expensive, so none was provided in the cost of the systems. It was assumed, instead, that electrical power be provided at the sites from at least two independent sources of power to insure an uninterrupted supply under any circumstance.

Screening and Grit Removal Facilities

Screening and grit removal equipment are included in the lagoon treatment systems at the equalization lagoons and at the aerated lagoons.

Design Criteria

Mechanically cleaned bar screens are used to remove debris from the influent flows. The screens are located immediately ahead of the tunnels to eliminate unnecessary trash from entering the system. The screening unit is based upon a maximum velocity through the screens of 2.5 feet per second, using 1/2" bars spaced with 2" clear openings. The 10 foot square units will pass 130 MGD each. This and other design data are summarized in Table III-5.

At the St. Clair Site there are 134 units required for the stormwater flow and 16 units for the municipal and industrial flow. The requirements at the Monroe Site are 85 units for the stormwater flow and 5 units for municipal and industrial flow. Debris collected at each screening location will be trucked to nearby land fill disposal areas.

Records from the City of Detroit indicate the grit quantities vary from the maximum of 6.5 to a minimum of 2.4 cubic feet per million gallons of wastewater. For design purposes, 5 cubic feet per million gallons is used.

Table III-5

GRIT & SCREENING DESIGN DATA

	St. Clair	Monroe
Equalization Lagoons		
Peak Stormwater Flows - MGD	17,420	10,970
Number of Grit Sedimentation Basins	2	2
Overflow Rate - Gal./Ft^2 Day	46,300	46,300
Basin Surface Area - Ft^2	376,000	237,000
Basin Water Depth - Ft.	24	24
Basin Freeboard - Ft.	6	6
Basin Height - Ft.	30	30
Number of Screening Units	150	90
Flow Rate/Unit - MGD	130	130
Screening Surface Area/ Unit - Ft^2	80	80
Treatment Sites		
Design Flow Rates - MGD	3,033	1,615
Number of Grit Chamber Units	32	17
Flow Rate/Unit - MGD	93	93
Unit Length - Ft.	115	115
Unit Width - Ft.	18	18

Table III-5 (Cont.)

GRIT & SCREENING DESIGN DATA

	St. Clair	Monroe
Treatment Sites (Con't)		
Unit Water Depth Ft.	8	8
Grit Deposition - Ft^3/MGD	5	5
Grit Accumulation by 2020- Yd^3	6,950,000	4,375,000
Disposal Area Required- Acres	50	30

The grit removal system is designed for the removal of particles 0.2 mm in diameter and larger having a specific gravity equal to or greater than 2.65. The velocity of 1 foot per second through the grit chamber is used to permit the settling of the grit and to keep the organic matter in suspension.

The peak stormwater flow into the equalization lagoons was given as 17,420 MGD, 10,970 MGD for St. Clair and Monroe systems, respectively. Out flow from the equalization lagoons will be at a constant rate of 1,055 MGD at each site. Combine peak flow rates at the grit chambers are 3,033 MGD at St. Clair and 1,615 MGD at Monroe.

Grit from the municipal and industrial flow will be removed in chambers located next to the aerated lagoons at each treatment site. The stormwater grit will be removed by sedimentation in isolated cells of the equalization lagoon.

Two 9-acre sedimentation basins will be built at each equalization lagoon to provide the reliability necessary for the operations of the systems. One basin at a time may be taken out of service for dredging and cleaning.

Costs

A summary of the costs for screening and grit removal facilities is shown in Table III-6. A more detailed list, including unit costs, is included in the Appendix.

Table III-6

COST SUMMARY FOR
SCREENING AND GRIT REMOVAL FACILITIES

	St. Clair	Monroe
Capital Cost		
Grit Removal-Structure	$3,120,800	$1,729,000
Grit Removal-Equipment	831,000	586,000
Screening Units-Structure	7,919,800	4,752,000
Screening Units-Equipment	6,000,000	3,600,000
Subtotal	$17,871,600	$10,667,000
Land	$ 37,600	$ 41,300
Engineering - 10%	1,787,200	1,066,700
Administration - 5%	893,600	533,400
Contingency - 10%	1,787,200	1,066,700
TOTAL	$22,377,200	$13,375,100
Operation and Maintenance/yr		
Labor (includes 25% overhead)	262,500	169,000
Trucking	24,800	13,000
Materials & Supplies (0.1% of Capital Cost)	178,700	106,700
TOTAL	$ 466,000	$ 288,700
Replacement Cost		
Mechanical Equipment - 5 years	$ 175,000	$ 125,000
Grit Removal Equipment - 10 years	200,000	200,000
Grit and Screening Equipment - 25 years	6,456,000	3,861,000

Performance and Reliability

There is adequate redundancy in the screening and grit removal facilities to insure reliable operation and satisfactory performance, even during maintenance operations.

AERATED LAGOONS

Wastewater from the grit chambers enters the aerated lagoons, where the Biochemical Oxygen Demand (BOD) is reduced by 70 to 90 per cent. This reduction in BOD is accomplished by an active mass of microorganisms in the lagoons that feed on the organic content of the wastewater and, in three days time, reduce the degradable organic content to an acceptable level for the storage lagoons. The large, floating surface aerators in the lagoons serve two essential functions; to entrain and dissolve sufficient quantities of oxygen to support the biological growth in the wastewater and to provide sufficient mixing to disperse the dissolved oxygen and to suspend the solids during aeration. The lagoons are designed for complete mixing so that there are no anaerobic conditions or areas of sludge settling.

Design Criteria

The design criteria for the aerated lagoons are listed in Table III-7. A lagoon size of 80 MGD was chosen to take advantage of the economies of scale. This size results in a requirement for 27 lagoons at the St. Clair Site and 17 at the Monroe Site. Each lagoon requires 51 acres of land and 36-150 HP aerators. The depth of the lagoon, aerator spacing and aerator design are chosen to ensure satisfactory oxygen transfer and complete mixing. A cross-section of a typical lagoon is shown in Figure III-4. Concrete is used as wave protection and soil cement is used in

Table III-7

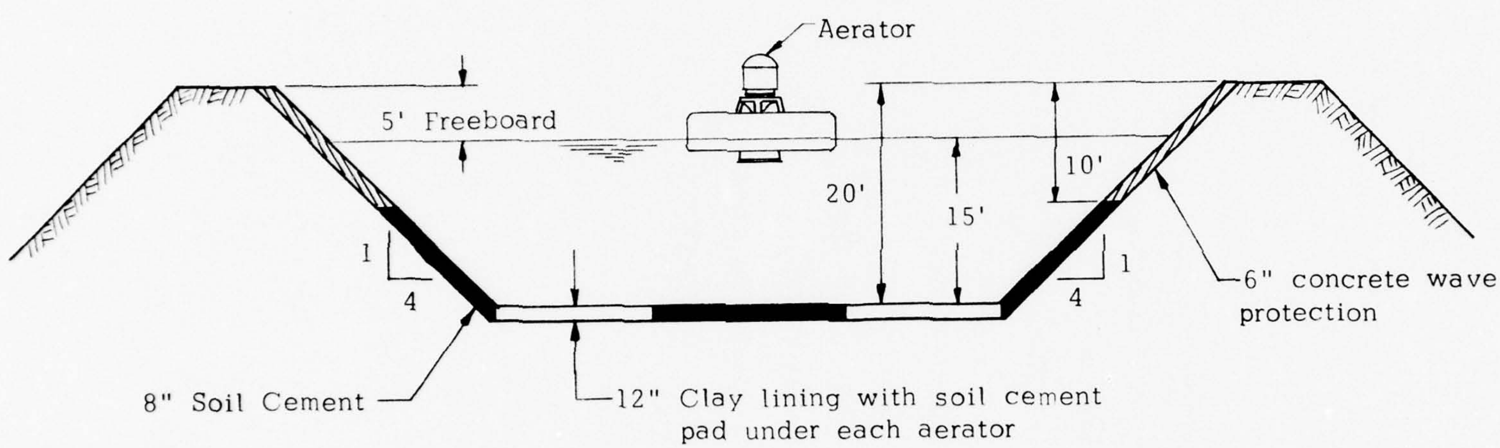
AERATED LAGOON DESIGN DATA

	St. Clair	Monroe
Detention Time-Days	3	3
Flow Rate/Lagoon-MGD	80	80
Number of Lagoons	27	17
Volume/Lagoon-MG	253	253
Volume/Lagoon-Acre-Feet	775	775
Land Area/Lagoon-Acres	57	57
Total Land Area-Acres	1,540	970
Total Land Area-Square Miles	2.4	1.5
Number of Aerators/Lagoon	36	36
Total Number of 150 HP Aerators	972	612
Oxygen Transfer Rate/Aerator lbs. O_2/Hour	432	432
Water Depth-Feet	15	15
Freeboard-Feet	5	5
Dike Height-Feet	20	20
Service Road Width-Feet	20	20

FIGURE III-4

TYPICAL AERATED LAGOON MODULE

CROSS-SECTION



underwater areas of potential erosion, on the side slopes and under the aerators. The clay lining is used to minimize seepage. A system of flumes, wiers and gates allows the lagoons to be used in series or parallel, or a single lagoon to be isolated from the system for maintenance.

The aerated lagoons are located toward the centers of the treatment sites, well away from public highways or residences. This minimizes any potential problems due to odors or aerosol effects from the aerated lagoons.

Alternatives

Aerated lagoons are chosen as treatment devices for this system because they are the least expensive (particularly with respect to operation and maintenance) and the most reliable method of reducing the BOD to levels acceptable for storage and irrigation. Aerated lagoons have the disadvantage of requiring large areas of land, but this is not a limiting factor in the Southeastern Michigan area.

An alternative that was studied extensively in the Survey-Scope Study of Wastewater Management for the Chicago-South End Lake Michigan Area was making use of existing secondary treatment plants in the urbanized area and conveying treated effluent to the land treatment sites. A study of this alternative for the Detroit metropolitan area was not within the scope of this report.

Costs

A summary of the costs associated with the aerated lagoons is shown in Table III-8. A more detailed listing, showing unit prices, is included in the Appendix. The only items requiring periodic replacement beyond normal maintenance activities are the 1584 aerators, each costing an estimated $35,000.

Performance and Reliability

The minimum performance expected in the aerated lagoons occurs during the winter, when the cooler temperatures reduce the activity of the biomass. The lagoons are designed so that even under these conditions the BOD reduction is 70%, or from an influent level of 88 and 61 mg/l to an effluent level of 27 and 19 mg/l at the St. Clair and Monroe sites, respectively, for combined wastewater and stormwater.

The multiple lagoon designs provides for maximum reliability in the aerated lagoons. Any loss of treatment capability in a lagoon, such as a severe industrial spill, can be relieved by bypassing that lagoon temporarily until it is corrected. The large size of the lagoons, 253 MG each, makes a toxic spill problem even more remote.

TABLE III-8

COST SUMMARY FOR AERATED LAGOONS

	St. Clair	Monroe
Capital Cost		
Earth Work	$ 7,678,000	$ 4,835,000
Slope, Bottom & Roadway Construction	17,574,000	15,034,500
Aerators	34,020,000	21,420,000
Electrical	5,832,000	3,672,000
Flumes	12,647,000	5,700,000
Subtotal	$77,751,000	$50,661,500
Land	$ 1,156,500	$ 1,336,700
Engineering - 10%	7,775,100	5,066,200
Administration - 5%	3,887,600	2,533,100
Contingencies - 10%	7,775,100	5,066,200
TOTAL	$98,345,300	$64,663,700
Operation and Maintenance/ year		
Power	$ 9,526,000	$ 5,998,000
Labor (includes 25% overhead)	2,675,000	1,681,000
Materials and Supplies (0.5% of Capital Cost)	388,800	253,300
TOTAL	$12,589,800	$ 7,932,300
Replacement Cost		
Aerators - 10 years	$34,020,000	$21,420,000

STORAGE LAGOONS

The storage lagoons in this project serve three special purposes. First, as a settling storage lagoon after the wastewater has passed through the aerated lagoon. This is where most of the sludge is collected. Second, a holding storage lagoon where the wastewater is held until it can be used for the irrigation process. And, third, for whatever biological action that can take place as stabilization of the remaining BOD by natural surface aeration and photosynthetic activity during the ice-free part of the year.

Design Criteria

Table III-9 lists the design data for the storage lagoons. All lagoons are approximately 2,000 acres in area, twenty feet deep with a seven foot freeboard and a three foot sludge settling depth. A flow per module of 80 MGD was chosen as the least cost alternative that would fit within the geography of the sites. Figure III-5 shows the cross-section of a typical square storage lagoon.

The flow from the aerated lagoons to the storage lagoons is by open flume. These flumes can direct the flow to any of the storage lagoons adjacent to the aerator lagoons. Most of the sludge is collected on the bottom of these nearby lagoons. Dredges will be assigned to these lagoons first when there is a 3-foot depth of sludge collected on the bottom.

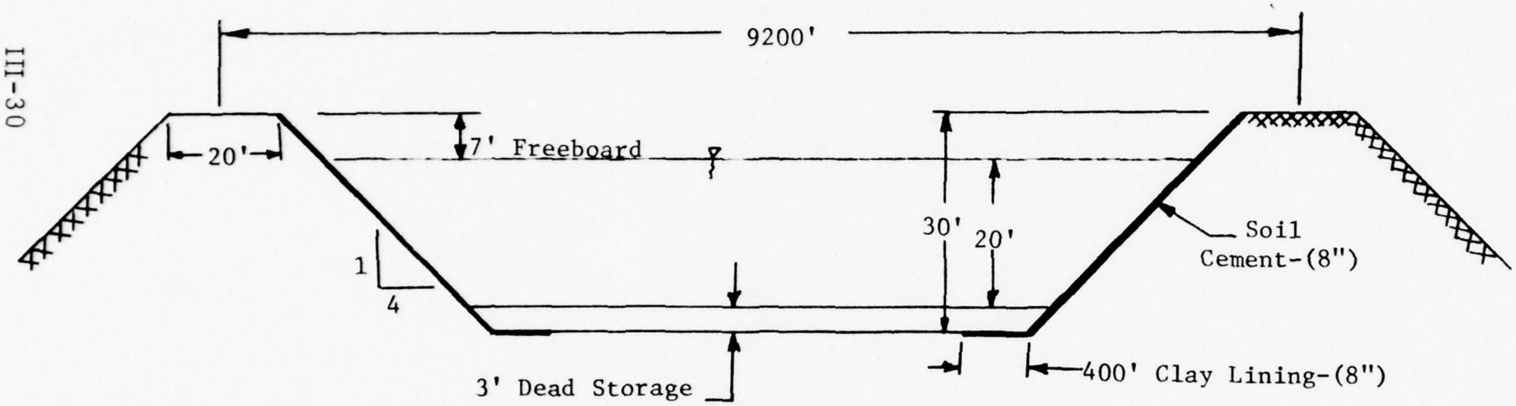
TABLE III-9

STORAGE LAGOON DESIGN DATA

	St. Clair	Monroe
Number of Lagoons	27	17
Volume/Lagoon-MG	12,679	12,679
Volume/Lagoon-Acre/Feet	38,861	38,861
Water Depth-Ft.	20	20
Freeboard-Ft.	7	7
Dead Storage-Ft.	3	3
Dike Height-Ft.	30	30
Land Area/Lagoon-Acres	2,000	2,000
Total Land Area-Acres	54,000	34,000
Total Land Area-Square Miles	84	53
Winter Storage Time-Days	155	155
Service Road Width-Ft.	20	20

FIGURE III-5

TYPICAL STORAGE LAGOON



Interconnecting structures between each set of adjacent lagoons allows the flow of water to be directed in either series or parallel, or to isolate a lagoon from the system. Figure III-6 shows a typical interconnecting structure.

The gravity flow of the wastewater through the storage lagoons is controlled by variable weirs and gates. In the St. Clair site the water for the seventeen northern storage lagoons is pumped by force main from the southern settling lagoons. Seepage from the storage lagoons is intercepted by ditches around the lagoons and is returned to the lagoons. The seepage control system is covered separately, elsewhere in this report.

The effluent from the storage lagoons must be chlorinated prior to its use for irrigation. For this purpose, seven chlorination facilities are located as part of the storage lagoons at the St. Clair Site and five chlorination facilities are located at the Monroe Site. Each chlorinator is located at a discharge point to the irrigation site. The chlorine dose will be adjusted during operation to achieve a maximum coliform bacteria count of 1000 per 100 ml. Open channels are assumed to be used after the chlorination facilities for a distance long enough to ensure adequate dechlorination time prior to irrigation. A typical chlorination facility is shown in Figure III-7.

Alternatives

Storage is necessary for 155 days to prevent having to discharge effluent without irrigation. The alternative of using less storage volume was not considered. Lagoons are the only economically feasible method of storing the required volume of water.

Costs

A summary of the costs associated with the storage lagoons is shown on Table III-10. A more detailed listing showing unit prices is included in the Appendix.

FIGURE III-6

INTERCONNECTING STRUCTURE

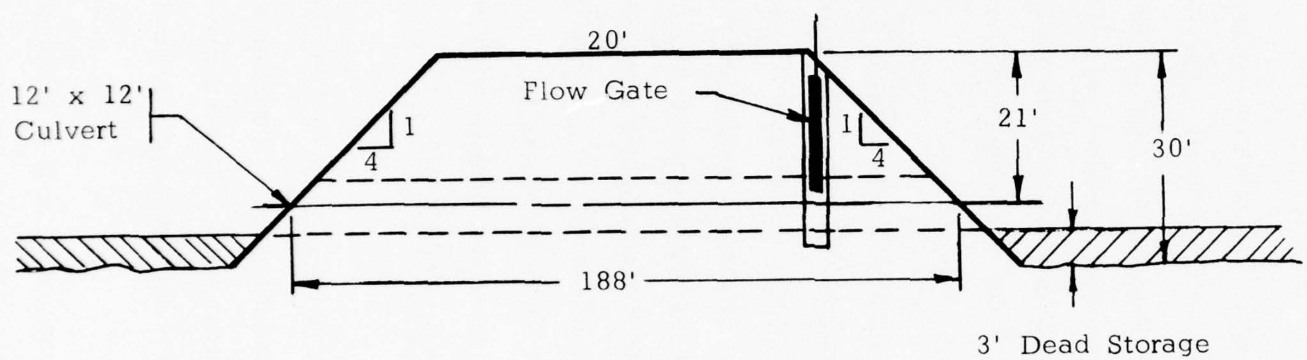


FIGURE III-7

OUTLET STRUCTURE WITH CHLORINATION FACILITIES

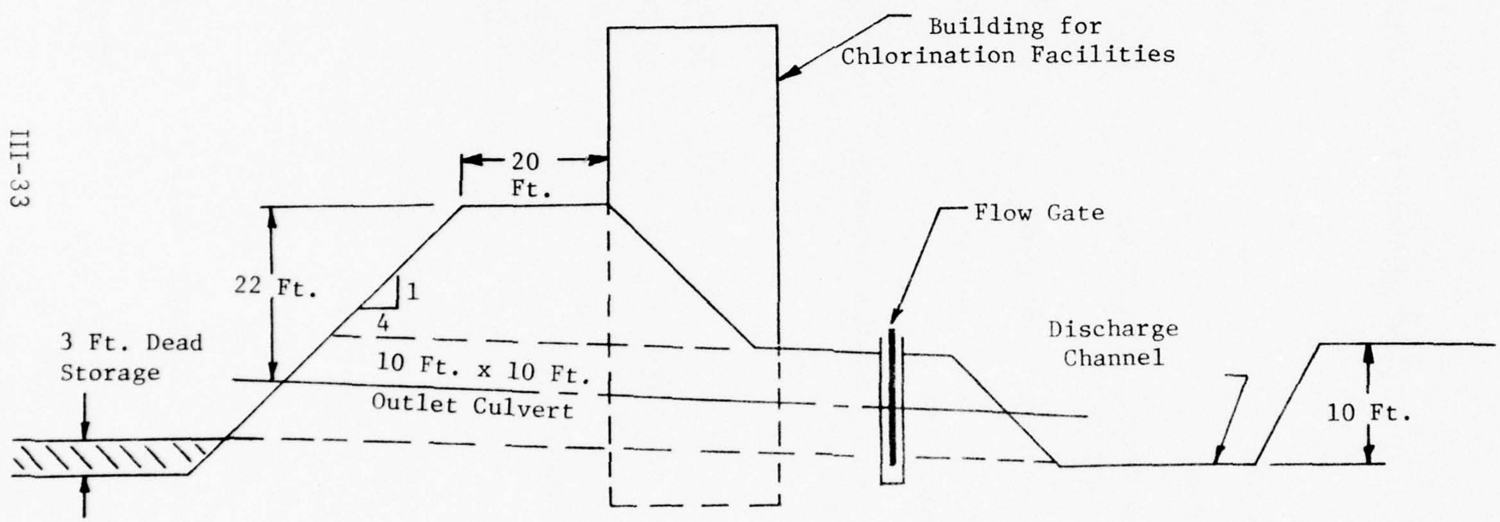


TABLE III-10

COST SUMMARY FOR STORAGE LAGOONS

Capital Cost	St. Clair	Monroe
Earthwork	$ 94,655,000	$ 59,600,000
Slope Bottom & Roadway Construction	40,144,000	49,103,500
Interconnection Structures	3,287,000	1,903,000
Outlet and Chlorination Structures	5,538,000	3,872,500
Conveyance System Between Sites	24,961,000	793,000
Subtotal	$ 168,585,000	$ 115,272,000
Land	40,554,000	46,852,000
10% Engineering	16,858,500	11,527,200
5% Administration	8,429,300	5,763,600
10% Contingency	16,858,500	11,527,200
Total	$ 251,285,300	$ 190,942,200
Operation and Maintenance/Year		
Labor (includes 25% overhead)	456,000	287,000
Chemicals - Chlorine @$0.05/# - 8 mg/l	2,661,000	1,674,000
Materials & Supplies (0.1% Capital Cost)	168,600	115,300
Total	$ 3,285,600	$ 2,076,300

Performance and Reliability

The successful operation of the lagoons is built into the use of modular units where each one may be isolated for repair and maintenance. All operational flow controls for the lagoons are done by variable weirs and gates.

Flow control of the water between storage lagoons during the winter season is not critical.

Chlorination equipment is simple in operation and control and there is little difficulty in its performance and reliability.

SEEPAGE CONTROL

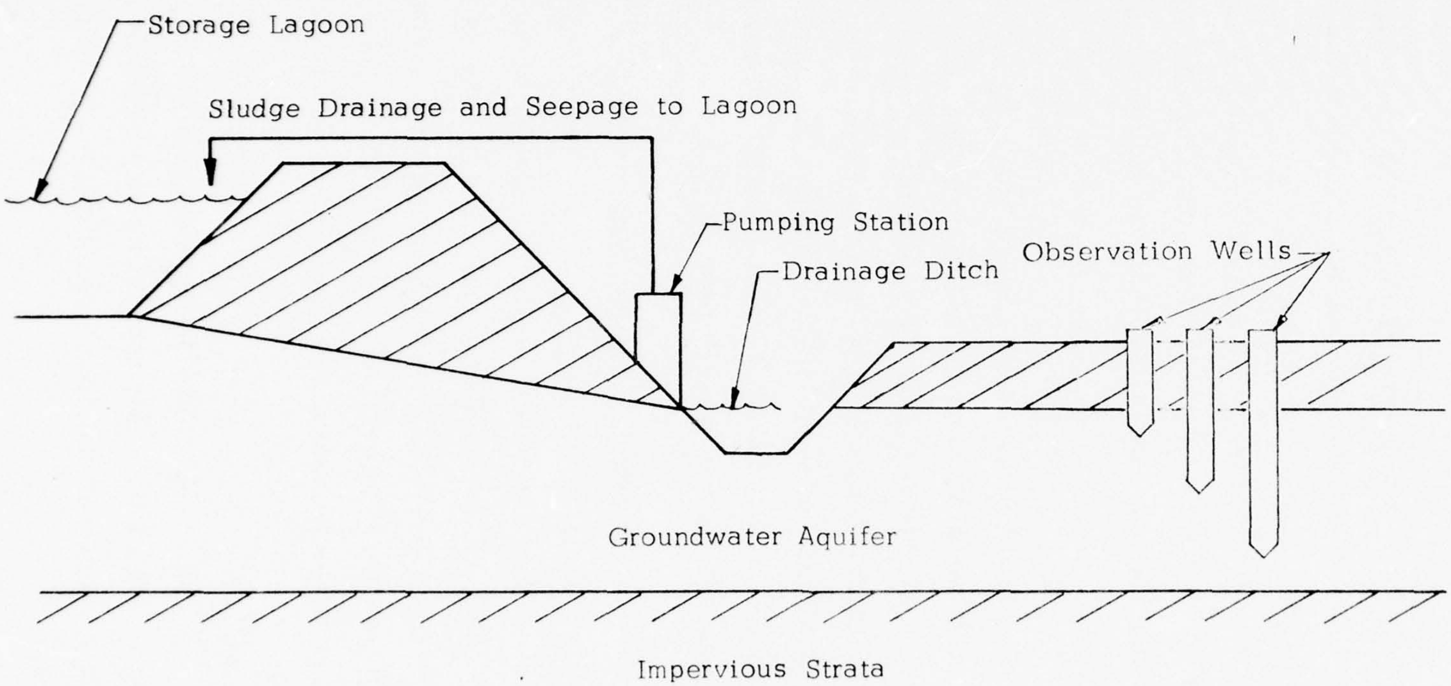
It is necessary to include in the design of the lagoon treatment system the facilities to control seepage of wastewater from the aerated lagoons, storage lagoons and sludge disposal areas. Included also is a monitoring system to allow any potentially harmful seepage to be detected and alleviated. The components of the seepage control system are shown in Figure III-8.

Design Criteria

Seepage from the aerated lagoons is limited by completely lining the lagoons with 12" of clay or, in areas of potential erosion, soil cement or concrete. A complete lining for the storage lagoons is not practical because of the very large area and resulting excessive costs. The design instead includes a 400' wide, 8" thick clay lining around the lagoon bottoms along the periphery of the storage lagoon sites. The side slopes of the lagoons are already protected by soil cement to prevent erosion as well as seepage. This clay lining along the edge of the lagoon sites aids in controlling the seepage. The initial maximum seepage from the lagoons of each treatment site is estimated to be 500 MGD. Since the plant will be placed in operation in phases during the construction period each new lagoon as it becomes operational will go thru a sealing process. This will reduce the above estimated amount of seepage. Based on the available data a 10' deep ditch was designed around the lagoon sites to intercept the seepage before it leaves the lagoon area.

FIGURE III-8

SEEPAGE CONTROL AND SLUDGE DRAINAGE SYSTEM



The only area where this ditch and the clay lining are not required is along nine miles of the lagoon at the St. Clair site where the lagoons are located on a clay base. Pumping stations, each having a capacity of 25,000 GPM and a lift of 38', are located at 4 mile intervals along the drainage ditches. The pumping stations return the water in the ditch to the storage lagoons.

The ditches serve another purpose, as well. The sludge disposal areas are located adjacent to the lagoons, and drainage from the sludge fields flows by gravity in the underdrain system to the ditch, from which it, too, is returned to the storage lagoons. The total flow from all sludge application operations is approximately 37 MGD, and thus can be easily accommodated by the pumping stations in the drainage ditches.

The monitoring system consists of 3-well clusters at 2,000' intervals along the drainage ditches. The clusters include three wells so that the water quality can be tested at the top, midpoint, and bottom of the aquifer. The wells are 1-1/4 inches in diameter and testing is done periodically by using a plunger to extract a water sample from each well. Table III-11 lists the design data for the seepage control system at each treatment site.

Alternatives

The system used for seepage control is a least cost alternative. Alternatives for preventing any seepage from the lagoons by the use of various lining materials are very much more expensive.

TABLE III-11

SEEPAGE CONTROL DESIGN DATA

	St. Clair	Monroe
Drainage Channels - Miles	52	57.5
Drainage Pumping Stations	14	15
Spacing of Pumping Stations - Miles	4	4
Pumping Station Capacity - gpm	25,000	25,000
Pumping Station Head - feet	38	38
Number of Observation Well Clusters	137	152
Observation Well Spacing - feet	2,000	2,000

Costs

Table III-12 shows the costs for the seepage control systems at each of the lagoon treatment sites. A more detailed breakdown of unit costs is included in the Appendix.

Performance and Reliability

The seepage control system has extensive redundancy in its design because the drainage ditches for each lagoon site are continuous and contain several pumping stations. If there is a failure in the system that results in the escape of seepage, the well clusters allow the failure to be detected. Because the movement of groundwater is very slow, adequate time exists for the implementation of corrective measures, including the placement of temporary well points or drainage wells.

TABLE III-12

COST SUMMARY FOR SEEPAGE CONTROL

Capital Cost	St. Clair	Monroe
Drainage Channel	$ 2,829,750	$ 3,144,000
Drainage Pumping Station	588,000	630,000
Observation Wells	86,250	95,000
Subtotal	$ 3,504,000	$ 3,869,000
10% Engineering	350,000	387,000
5% Administration	175,000	193,500
10% Contingency	350,000	387,000
Total	$ 4,379,000	$ 4,836,500
Operation & Maintenance/Year		
Power	$ 2,900,000	$ 3,110,000
Labor (includes 25% overhead)	100,000	100,000
Material and Supplies (0.5% Capital Cost)	21,900	24,200
Total	$ 3,021,900	$ 3,234,200

SLUDGE MANAGEMENT SYSTEMS

While in the aerated lagoons, most of the constituents in the wastewater are stabilized and converted to solids slightly more dense than water. The aerated lagoons are designed to keep these solids in suspension until this water is discharged to the storage (settling) lagoons. Those storage lagoons nearest the aerated lagoons act as settling ponds and it is here where most of the solids settle to the bottom as sludge. This material digests and becomes more concentrated until the settled sludge is about 12% solids. Dredges are used to remove the sludge from the lagoon bottoms and a system of pipes and roll-over plows is used to spread it on the lands adjacent to the lagoons. The sludge acts as a soil conditioner to increase the humus content and fertility of the soil. Figure III-9 shows the components of the sludge management system.

Design Criteria

The design of the sludge management system is based on a sludge solids generation rate of 0.8 tons per million gallons of municipal-industrial wastewater treated. This value is typical for large metropolitan areas. It was assumed that the stormwater contributes a neglegable amount of sludge at the lagoon treatment sites.

The storage lagoons are designed for a three-foot dead storage area for sludge storage at the bottom of the lagoon. If the sludge was evenly distributed throughout the lagoons, this would correspond to about 17 years of storage. Since most of settling will take place in a few lagoons, however, removal of the sludge could begin soon after the system becomes operational.

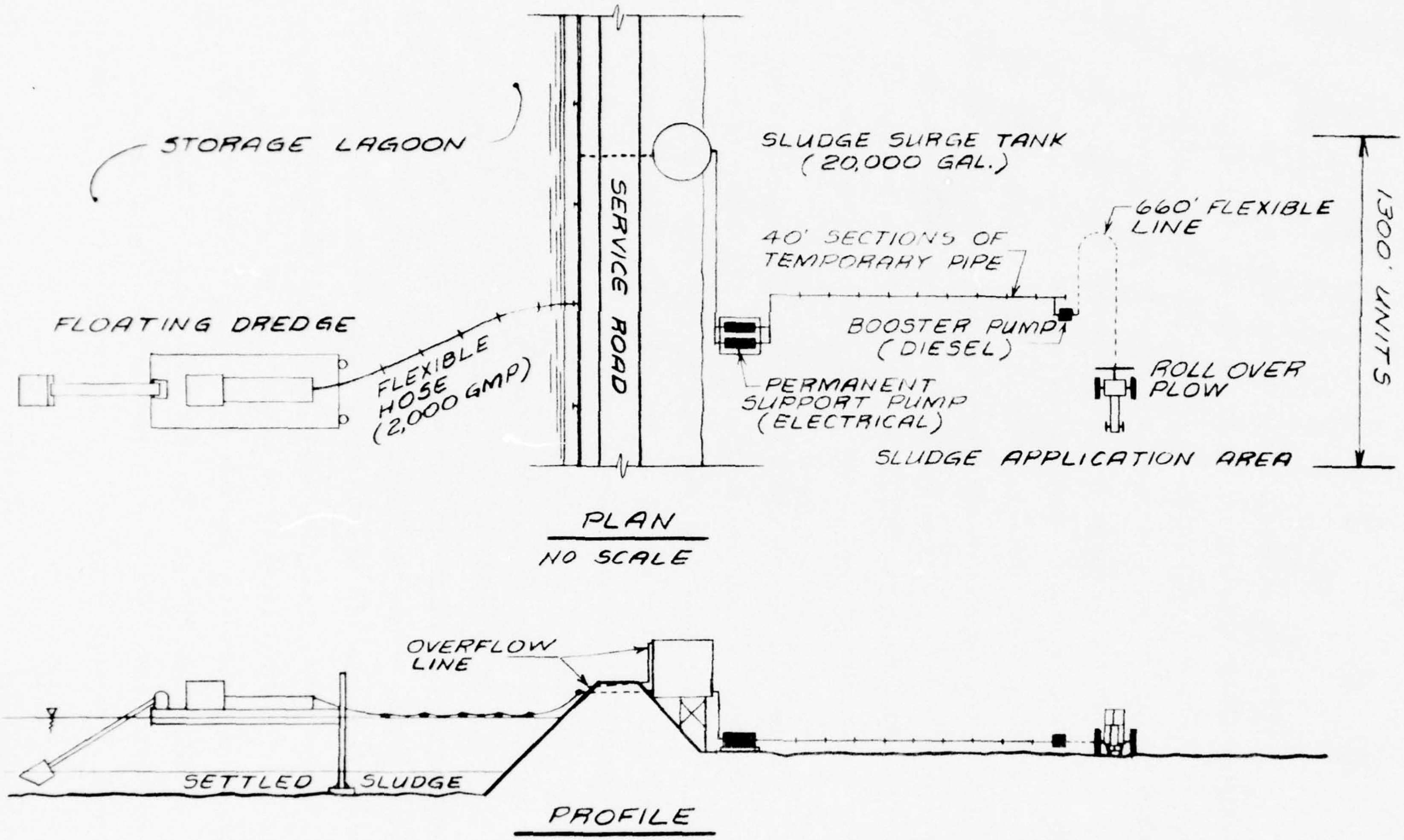


FIGURE III-9

SLUDGE MANAGEMENT SYSTEM

Dredges with rotating, screw-type, blades are used to remove the sludge from the bottom of the lagoons. The lagoon site has been designed so that more than one dredge can work in each lagoon. Once an assembled dredge is placed in a lagoon, it will not normally have to be transferred to another lagoon. The sludge at the bottom of the lagoons will be approximately twelve percent solids by weight. When it is removed by the dredge, the sludge will mix down to about six percent solids before it is brought to the surface. The sludge will be pumped from the dredge through a floating flexible pipe to a permanent header pipe system located on the berms of the storage lagoons.

Because of the high solids loading of the sludge, about 6% by weight, a minimum velocity of 3.5 ft. per second is required in the pipelines to prevent settling. In order to maintain this velocity, a portable pump is attached to the floating pipe at the dredge. There is another pump permanently located on the berm of the lagoon to pump the sludge through a surge tank to the disposal area. There is a pumping station and force main at the St. Clair site to transport sludge from the southerly storage lagoons, where most of the settling occurs, to the northerly sludge disposal areas. When the sludge reaches the fields it is transported through a header system and a series of electric pumps. The electric pumps boost the sludge through aluminum pipe sections, each section being 40' in length. At the terminus of the aluminum pipe there is a portable diesel pump which boosts the flow of the sludge through a flexible hose which is connected to the roll over plow. The plow is used to apply the sludge onto the land. The plow is pulled by a tractor back and forth across

the field in section widths of 1300'. Each time the tractor and plow complete 6 cycles a new aluminum pipe section is connected and the tractor and plow continue. In this manner each plow covers some 24 acres a day, spreading sludge containing 6% solids on 120 acres of land a week. At this rate of placing sludge on the land, the tractor pulling the plow would have to have a velocity of 6 miles per hour to allow for turning time and a 50 minute work hour.

Placement of the sludge onto or into the ground requires some type of equipment to disturb the earth's surface so the sludge may be readily absorbed into the ground. Failure to obtain satisfactory absorption would result in excessive runoff. So the equipment must be a type of scarifier with a method of placing the sludge into the ground. The best results to date have been with the roll over plow, although new methods are still being developed.

Each time the sludge velocity in the pipes slows to below 2.5 feet/second and at the end of each work day the system must be completely flushed. This may be done by running irrigation water through the sludge system.

The entire sludge disposal area has an underdrain system that discharges into the trenches around the lagoons (which are used primarly for seepage control) and the flow is returned to the lagoons by pumping stations in the ditches. Table III-13 summarizes the design data for the sludge management systems.

<u>Alternatives</u>

Alternative methods of removing sludge from the bottoms of the lagoons were examined.

TABLE III-13

SLUDGE MANAGEMENT DESIGN DATA

	St. Clair	Monroe
Dry Solids Generation - Tons/MG	0.8	0.8
Dry Solids Application Rate - Tons/Acre	10	10
Municipal-Industrial Design Flow Rates MGD	1130	320
Sludge Disposal Area - Square Miles	52	15
Minimum Sludge Velocity in Pipelines - Ft./Sec.	3.5	3.5
Number of Dredge-plow Systems	10	3

In smaller basins that are easily drained the sludge can be handled by a scraper system. Settling lagoons of this type are usually less than 1,000 feet square. These storage lagoons are over 9,000 feet square, and the handling of sludge in this manner would require an excessive number of trucks to transport sludge to the fields.

Sludge at 10% to 12% by volume is only slightly more dense than water. Because of this physical property, efficient removal of sludge from the lagoon bottom is difficult. Scraping with a dragline was reviewed but it was determined that too much turbulance was caused by the scraper and too much dilution of the sludge with the water while being raised to the surface. This method would result in a greater dilution of the sludge than the dredge system.

At this time there is no practical alternative to dredges for the removal of sludge from the lagoon bottoms. The future may offer new technology choices that will improve the efficiency of sludge removal.

A specific requirement for transporting sludge is to maintain a velocity of 3.5 ft./sec. Failure to do so will result in the sludge settling out of suspension. This requirement makes it necessary to transport all sludge in a pipe system. Open flow drains would require a steep slope to maintain the velocity so sedimentation would not take place. At the terminus of the open flow drain a sump would be necessary to transport the sludge from the drain through a pressure pipe to the roll over plow. The costs of open drains for the sludge would thus be excessive.

Costs

A summary of the costs associated with the sludge management system is shown in Table III-14. A more detailed listing, showing unit prices, is included in the Appendix.

Performance and Reliability

A surge tank is included in each system to take care of the variable flow of the dredge (or dredges) and the plow (or plows). Overflow from the surge tank is returned to the settling lagoon from which it came. If a dredge breaks down one plow unit can be taken off the line, if a plow unit breaks down, another unit could replace it, should it be necessary.

The dredges chosen for this project are portable so they may be broken down, transferred to a new lagoon, and reassembled in a short time. The system is quite flexible and in this manner, reliability is built into the process.

TABLE III-14

COST SUMMARY FOR SLUDGE MANAGEMENT

	St. Clair	Monroe
Capital Cost		
Drainage System	$ 21,223,800	$ 6,530,400
Equipment	3,718,000	1,115,400
Header Pipe	15,346,200	3,903,000
Pump Stations	1,013,900	195,000
Sub Total	$ 41,301,900	$11,743,800
Land	$ 25,000,000	$13,200,000
Engineering-10%	4,130,200	1,174,400
Administration-5%	2,065,100	587,200
Contingency - 10%	4,130,200	1,174,400
Total	$ 76,627,400	$27,879,800
Operation and Maintenance Cost		
Power	$ 29,700	$ 8,400
Labor (includes 25% overhead)	2,060,000	620,000
Material and Supplies	1,050,000	315,000
	$ 3,139,700	$ 943,400
Replacement Costs		
Header Pipe & Pump Stations-25 years	$ 16,360,100	$ 4,098,000

RENOVATED WATER CONVEYANCE SYSTEM

After treatment by the "Living Filter" in the spray irrigation areas of the land treatment system, the resulting effluent or renovated water is collected by the irrigation area's underdrain system and discharged into the renovated water conveyance system for transmission to its ultimate discharge point.

This conveyance system, is included as a part of this study. For the large flows involved in this study, open channels and mole tunnels are the best solutions to this conveyance design problem. The renovated water is of such a quality as to allow it to be conveyed without concern for its contamination of the surrounding groundwater.

Design Criteria

Both gravity flow in open channels and mole tunnels flowing full are utilized in the design of the St. Clair and Monroe renovated water conveyance systems. The mole tunnel designs for these systems are based on the Chicago experience already mentioned in the wastewater conveyance section of this study. Renovated water tunnels and channels, however, are designed for a constant flow of water rather than for a peak flow as is the wastewater system.

The mole tunnels for the renovated water conveyance systems are designed with circular cross-sections. They are to be located in suitable rock strata so that their walls will be

smooth enough for use without an additional lining. Geological information provided by the CORPS is used when available to assist in the vertical positioning of these tunnels. Since there is a minimal danger of ground water contamination it is not a concern, and so the conveyance tunnels for this system are designed for full flow. In this way the existing hydraulic head in each system may be used to full advantage, and eliminate the need for pumping stations.

The open channel portions of these conveyance systems are designed with trapezoidal cross-sections. They operate by gravity and are designed for a maximum velocity of 2.5 feet per second as a safeguard against channel erosion. Velocity control sections are used when velocities in the channels cannot be controlled by the channel slope alone. Channel linings are not included in the designs as groundwater contamination is not a concern of these systems.

Exhibit 3 gives the plan and profile of the St. Clair renovated water conveyance system. This system incorporates both open channels and a mole tunnel. The renovated water is picked up in open channels at two locations in the St. Clair irrigation site and is conveyed by these channels to the entrance of the tunnel. The water is transmitted through the tunnel and discharged into the St. Clair River at Marysville. There is sufficient hydraulic head in the tunnel system to overcome the head losses developed during transmission, thus eliminating the need for a pumping station. The pertinent design data for this conveyance system are listed in Table III-15.

The plan and profile of the Monroe renovated water conveyance system are given in Exhibit 4. This system requires the use of a mole tunnel only. The water from the Monroe irrigation site is collected by the irrigation drainage system and conveyed to the entrance of the tunnel. The water is transmitted through the tunnel and is discharged into Lake Erie at Monroe. There is sufficient hydraulic head in the tunnel system to overcome the head losses developed during transmission, thus eliminating the need for a pumping station. The pertinent design data for this conveyance system are also listed in Table III-15.

Alternatives

The selection of the open channel and mole tunnel alternatives for these conveyance systems are based on similar criteria to those used for the wastewater conveyance systems. The final selection of a tunnel size is based on the economic analysis of several possible design alternatives. Each alternative consists of a specific tunnel diameter, the associated head losses, and the pumping station requirements of the system. These possible combinations are compared by calculating the tunnel and pump station annual costs for each possibility and selecting the design with the lowest overall annual cost as optimal for the system.

Costs

The cost summaries for the renovated water conveyance systems are given in Table III-16. Unit costs and more detailed information on these systems are included in the Appendix.

TABLE III-15

RENOVATED WATER CONVEYANCE
SYSTEM DESIGN DATA

Location	St. Clair		Monroe
Exhibit No.	3	3	4
Total Length Miles	10.9	15.4	10.6
Type of Line	Tunnel	Open Channel	Tunnel
Diameter, Feet	20.0	--	15.0
Design Flow MGD	2,148.0	2,148.0	665.0
No. of Pump Stations	--	--	--
Pump H.P. Per Station	--	--	--
Channel Slope Ft/1000 Ft.	--	0.1	--

Performance and Reliability

The use of open channels and conveyance tunnels without pumping stations for these systems results in reliable water conveyance systems that perform well over a wide range of conditions. A constant flow rate, the good quality of the water transmitted, and the favorable hydraulic head are the important factors which allow for this type of design. These factors minimize system requirements for mechanical and electrical equipment. They also minimize the operational control and regular maintenance that is required to keep the systems functioning properly.

TABLE III-16

COST SUMMARY FOR RENOVATED WATER CONVEYANCE SYSTEM

Capital Cost	St. Clair	Monroe
Tunnel	$30,545,500	$20,448,000
Drop Shafts	1,324,000	503,200
Open Channel	3,841,000	-
Subtotal	35,710,500	20,951,200
10% Engineering	3,571,100	2,095,100
5% Administration	1,785,500	1,047,600
10% Contingency	3,571,100	2,095,100
TOTAL	$44,638,200	$26,189,000
Operation and Maintenance/Year		
Labor (includes 25% overhead)	$ 71,400	$ 42,500
Materials & Supplies		
Tunnel & Channel	35,700	21,000
TOTAL	$ 107,100	$ 63,500

Time Phasing

The construction and the initial operation of the Land Treatment System will require a scheduling sequence such as is discussed here. Construction of all components need not be completed simultaneously, so each of the particular units are discussed with respect to; (a) Initial Startup, (b) One-half Capacity, and (c) Full Capacity. It is assumed that the following conditions will prevail during construction.

1. All municipal facilities presently in existence can be used to support the new Land Treatment System until fully operational.

2. Coordination of construction for projects outside this facility would be tied to this construction program for maximum effectiveness.

3. Each of the Land Treatment Systems can be constructed and operated independently.

Initial Startup

At the initiation of operations of the system, only a portion of the design capacity may be required, and the entire system will require a testing or checkout period. The requirements for each of the components is discussed briefly for this period.

Equalization Lagoons - If stormwater is to be treated at the initiation of operations, at least one lagoon, with its associated screening and grit removal facilities, must be operational.

Wastewater Conveyance - This tunnel is the most essential first component to be completed. The pumping station need be only partially operational, depending on the flow, but any additional work must be possible while the tunnel and pumping station are operating.

Aerated Lagoons - Enough aerated lagoons, as well as screening and grit removal chambers, must be completed to allow the required three-days detention for the initial flow rate.

Storage Lagoons - Only a part of the storage lagoons will have to be available at startup. For summer operation, it may be sufficient to have a single lagoon for settling if the flow is low enough. Chlorination must be provided for all wastewater being discharged.

Seepage Control - The ditches, pumping stations, and monitoring wells must be operational for those lagoon sites to be used for startup.

Sludge Management - The sludge management facilities need not be operational for quite a length of time after startup

although a testing program to verify the operational characteristics of the system will be important.

Irrigation and Drainage Facilities - A complete testing and cropping program will be important as soon as the system is operational. Only those irrigation and drainage facilities required for the startup flows need be operational, however.

Renovated Water Conveyance - The tunnel to convey renovated water from the land treatment site must be completely operational at system startup.

Operation at One-Half Capacity

It was assumed that one-half capacity was equal to a single equalization lagoon capacity (enough to manage the first flush of stormwater) plus one-half of the design municipal-industrial flow. Requirements for the components for one-half capacity are discussed.

Equalization Lagoons - Only one lagoon will have to be operable, but all of the screening and grit removal facilities will be required to treat the full flow. A method of bypassing or redirecting the excess stormwater will have to be provided, along with any chlorination facilities required for disinfection of the bypass stormwater.

Wastewater Conveyance - Only one-half the pumping capacity will have to be operational, although full operational capability is recommended.

Lagoons - About one-half of the aerated and storage lagoons must be completed for year-round operation if the discharge of stormwater is one-half the design flow. Chlorination facilities are required for one-half design flow.

Seepage Control - Seepage control must be completed for the lagoons in operation.

Sludge Management - The underdrain system for about one-half of the sludge disposal should be laid and about one-third of the sludge handling equipment should be on site and ready for operation. It may be several years, however, before sludge would have to be removed from all of the lagoons being used.

Irrigation and Drainage Facilities - About one-half of these areas must be operational for year-round operation with one-half design capacity.

Operation at Full Capacity

All components of the system must be fully operational with the system at full capacity, with the exception of the sludge management system. The mode of operation of the settling and storage lagoons will dictate how long before a

steady state, when the sludge removed equals the sludge generated, is reached. Only when this steady state is reached, will the complete sludge management system be required.

The inherent flexibility of a land treatment system makes the schedule for construction and operation a function of the initial performance objectives. These must be carefully specified throughout the implementation phase of the project.

SECTION IV

COST SUMMARIES OF LAGOON TREATMENT SYSTEMS

COST SUMMARIES OF LAGOON TREATMENT SYSTEMS

Table IV-1 "Cost Summary Lagoon Treatment System" is a combining of all cost information for both sites. Backup information for all data can be found in Section III under each of the component headings.

Tables IV-2, IV-3, and IV-4 are System Cost Summaries where the Annual Cost is at 5 1/2%, 7% and 10% interest. Each item can be found in detail under its component headings.

TABLE IV-1

COST SUMMARY LAGOON TREATMENT SYSTEM

	St. Clair	Monroe
CAPITAL COST		
Equalization Lagoons	$ 15,872,500	$ 13,872,500
Conveyance System -Wastewater	153,511,500	110,204,000
Grit Removal & Screening	22,377,200	13,375,100
Aerated Lagoons	98,345,300	64,663,700
Storage Lagoons	251,285,300	190,942,200
Seepage Control	4,379,000	4,836,500
Sludge Management	76,627,400	27,879,800
Conveyance System-Renovated Water	44,638,200	26,189,000
TOTAL	$667,036,400	$451,962,800
OPERATION & MAINTENANCE COST - 1 YEAR		
Equalization Lagoons	$ 121,000	$ 121,000
Conveyance System-Wastewater	19,579,800	8,882,100
Grit Removal & Screening	466,000	288,700
Aerated Lagoons	12,589,800	7,932,300
Storage Lagoons	3,285,600	2,076,300
Seepage Control	3,021,900	3,234,200
Sludge Management	3,139,700	943,400
Conveyance System-Renovated Water	107,100	63,500
	$42,310,900	$ 23,541,500

TABLE IV-1 (Cont.)

COST SUMMARY LAGOON TREATMENT SYSTEM

	St. Clair	Monroe
REPLACEMENT COST		
Conveyance System-Wastewater		
Pump Station-20%-25 years	7,082,400	5,774,800
15%-10 years	5,311,800	4,331,100
Grit Removal & Screening		
Mechanical Equipment - 5 yrs.	175,000	125,000
Grit Removal Equipment-10 yrs.	200,000	200,000
Grit & Screening Equipm.-25 yrs.	$ 6,456,000	$ 3,861,000
Aerated Lagoons		
Aerators - 10 yrs	34,020,000	21,420,000
Sludge Management		
Header Pipe & Pump Station -25 yrs.	16,360,100	4,098,000

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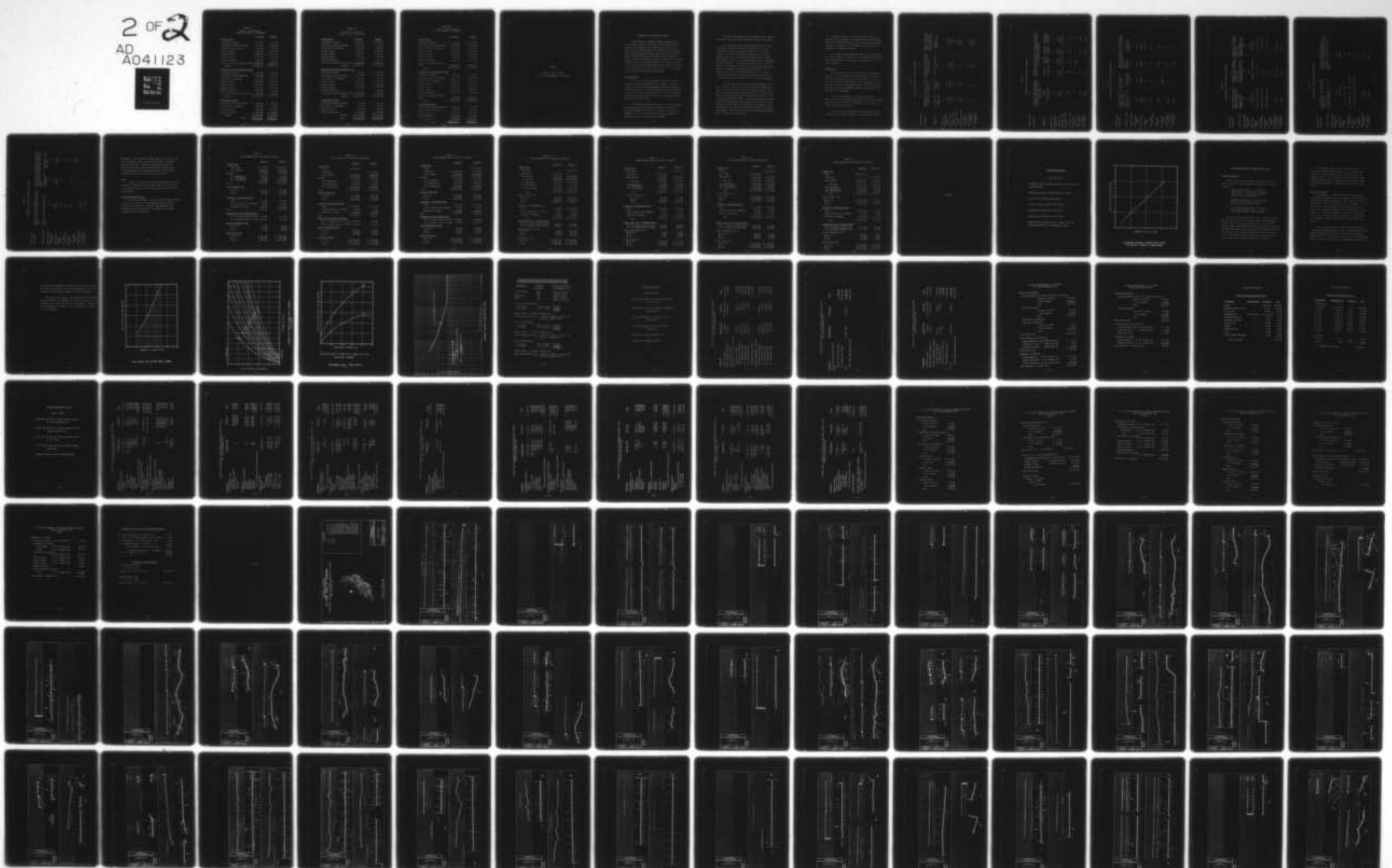


TABLE IV-2

SYSTEM COST SUMMARY
ANNUAL COST @ 5-1/2% INTEREST

	St. Clair	Monroe
CAPITAL COST		
Equalization Lagoons	$ 937,400	819,300
Conveyance System-Wastewater	9,066,400	6,508,600
Grit Removal & Screening	1,321,600	789,900
Aerated Lagoons	5,808,300	3,819,000
Storage Lagoons	14,840,900	11,277,000
Seepage Control	258,600	285,600
Sludge Management	4,525,600	1,646,600
Conveyance System-Renovated Water	2,636,300	1,546,700
Subtotal	$39,395,100	$26,692,700
OPERATION AND MAINTENANCE COST		
Equalization Lagoons	$ 121,000	$ 121,000
Conveyance System-Wastewater	19,579,800	8,882,100
Grit Removal & Screening	466,000	288,700
Aerated Lagoons	12,589,800	7,932,300
Storage Lagoons	3,285,600	2,076,300
Seepage Control	3,021,900	3,234,200
Sludge Management	3,139,700	943,400
Conveyance System-Renovated Water	107,100	63,500
Subtotal	$42,310,900	$23,541,500
REPLACEMENT COST		
Conveyance System-Wastewater	$ 498,600	$ 406,500
Grit Removal & Screening	144,400	95,500
Aerated Lagoons	2,504,000	1,577,000
Sludge Management	253,300	63,500
Subtotal	$ 3,400,300	$2,142,500
TOTAL	$85,106,300	$52,376,700

TABLE IV-3

SYSTEM COST SUMMARY
ANNUAL COST @ 7% INTEREST

CAPITAL COST	St. Clair	Monroe
Equalization Lagoons	$ 1,150,100	$ 1,005,200
Conveyance System-Wastewater	11,123,400	7,985,400
Grit Removal & Screening	1,621,500	969,200
Aerated Lagoons	7,126,100	4,685,500
Storage Lagoons	18,208,100	13,835,700
Seepage Control	317,300	350,500
Sludge Management	5,552,400	2,020,200
Conveyance System-Renovated Water	3,234,500	1,897,700
Subtotal	$48,333,400	$32,749,400
OPERATION AND MAINTENANCE COST		
Equalization Lagoons	$ 121,000	$ 121,000
Conveyance System-Wastewater	19,579,800	8,882,100
Grit Removal & Screening	466,000	288,700
Aerated Lagoons	12,589,800	7,932,300
Storage Lagoons	3,285,600	2,076,300
Seepage Control	3,021,900	3,234,200
Sludge Management	3,139,700	943,400
Conveyance System-Renovated Water	107,100	63,500
Subtotal	$42,310,900	$23,541,500
REPLACEMENT COST		
Conveyance System-Wastewater	$ 466,000	$ 380,000
Grit Removal & Screening	130,200	86,900
Aerated Lagoons	2,379,000	1,498,000
Sludge Management	218,400	54,700
Subtotal	$ 3,193,600	$ 2,019,600
Total	$ 93,837,900	$58,314,500

TABLE IV-4

SYSTEM COST SUMMARY
ANNUAL COST @ 10% INTEREST

	St. Clair	Monroe
CAPITAL COST		
Equalization Lagoons	$ 1,600,900	$ 1,399,200
Conveyance System-Wastewater	15,483,200	11,115,200
Grit Removal & Screening	2,257,000	1,349,000
Aerated Lagoons	9,919,100	6,522,000
Storage Lagoons	25,344,600	19,258,400
Seepage Control	441,700	487,800
Sludge Management	7,714,800	2,812,000
Conveyance System-Renovated Water	4,502,200	2,641,400
Subtotal	$67,263,500	$45,585,000
OPERATION & MAINTENANCE COST		
Equalization Lagoons	$ 121,000	$ 121,000
Conveyance System-Wastewater	19,579,800	8,882,100
Grit Removal & Screening	466,000	288,700
Aerated Lagoons	12,589,800	7,932,300
Storage Lagoons	3,285,600	2,076,300
Seepage Control	3,021,900	3,234,200
Sludge Management	3,139,700	943,400
Conveyance System-Renovated Water	107,100	63,500
Subtotal	$42,310,900	$23,541,500
REPLACEMENT COST		
Conveyance System-Wastewater	$ 394,500	$ 321,700
Grit Removal & Screening	101,000	68,800
Aerated Lagoons	2,105,000	1,325,000
Sludge Management	152,300	38,100
Subtotal	$ 2,752,800	$ 1,753,600
TOTAL	$112,327,200	$70,880,100

SECTION V

DESIGN AND COSTS OF CONVEYANCE SYSTEMS

ADDITIONAL CONVEYANCE SYSTEMS

Besides the four conveyance systems required for the land treatment systems of this study, fourteen additional conveyance system designs are included in this section at the request of the Detroit-District, U.S. Army Corps of Engineers. These additional systems include tunnels, force mains, and gravity interceptors designed for various flow and water conditions. Three of these systems convey effluent from the lagoon treatment systems to isolated irrigation sites, while the other eleven systems transport wastewater to the equalization lagoons, to the land treatment sites, or from points in the metropolitan area to advanced wastewater treatment plants.

Design Criteria

All of the conveyance systems in this section are designed using the flows supplied by the CORPS. For those systems conveying municipal-industrial or combined wastewater, the conveyance system is sized to handle a peak flow assumed to be 1.75 times the average daily flow. For those systems conveying only treated water, the flow was assumed to remain constant at the given value.

The CORPS data specified the type of conveyance system to be used in most cases or gave a choice of a tunnel or a gravity interceptor in the rest. In all cases, however, consideration is given to using the best possible system from an engineering as well as an economic viewpoint.

The mole tunnel systems use the design criteria already discussed in the wastewater conveyance section of this report.

The gravity interceptors have sufficient size and slope to maintain a minimum velocity of 2.0 feet per second at average daily flow and a minimum velocity of 1.5 feet per second at a minimum daily flow assumed to be 0.75 of the average daily flow. Reinforced concrete pipe with a circular cross-section is used in all gravity systems, and all interceptors are sized using a $n = 0.015$ in Manning's formula. The final design of each interceptor takes into account the existing ground profile. It is based on excavation not exceeding a 20 foot depth unless it is economically beneficial to do so, and it minimizes the number of lift stations required for each system by varying the size and slope of each line to fit the topography.

The force main systems have sufficient diameter to maintain a minimum velocity of 5 feet per second at average daily flow. No peaking factor is used in these designs as all force mains convey treated water to irrigation sites. The force mains all have circular cross-sections and are sized using a $C = 100$ in the Hazen-Williams formula. Pump station capacity and power requirements are based on the average daily flow and the head required to lift the water to the irrigation site elevation and to compensate for the head losses developed within the line during transmission. All force mains follow the existing ground profile with a minimum of 5 feet of cover.

Exhibits 5 through 18 give the plans and profiles of these conveyance systems. All systems follow existing public right-of-ways whenever possible, and all geological information available is shown when it is beneficial to the selection or positioning of a particular system.

The pertinent design data for these conveyance systems are listed in Tables V-1 through V-6. The diameters and slopes of the lines involved in each system are also shown on the profile drawings.

Alternatives

The selection of a mole tunnel and its related pumping station is done in accordance with the procedure discussed in the wastewater conveyance section of this report. In making the choice between a tunnel and a gravity interceptor, both the proposed route of the conveyance system and the magnitude of the flow involved are important factors to consider along with the economic considerations.

The final configuration of a gravity interceptor is based largely on the existing ground profile and the configuration requiring the least number of lift stations, in most cases, is the optimal design for the system.

The selection of a force main and pump station system is based on the economic analysis of several possible design

TABLE V-1

CONVEYANCE SYSTEM DESIGN SUMMARY

System Name	A		B	C
Description	Interceptors from St. Clair Twp. and Algonac to Treatment Plant at East China Township		Interceptor from Port Huron to Treatment Plant at East China Township	Tunnel in Rock from Detroit to Treatment Plant at the mouth of the Huron River
Location of Line	St. Clair Twp. to Treatment Plant	Algonac to Treatment Plant	Port Huron to Treatment Plant	Detroit to Treatment Plant
Exhibit No.	5	5	6	7
Total Length, Miles	4.8	10.9	16.7	24.6
Type of Line	Gravity	Gravity	Gravity	Tunnel
Diameter, Feet	3.0	3.0	5.0 & 6.0	20.0
Ave. Daily Flow, MGD	6.0	6.0	24	806
Peak Flow, MGD	10.5	10.5	42	1410
No. of Pump Stations	2	4	4	1
Max. Pump H.P. Per Station	58	58	230	82,300
Ave. Pump H.P. Per Station	33	33	132	47,100

TABLE V-2

CONVEYANCE SYSTEM DESIGN SUMMARY

System Name	D	E			
Description	Tunnel in rock (or interceptor in glacial drift) from Monroe to Plant at the mouth of the Huron River	Interceptor from Port Huron through E. China TWP, Algonac and New Baltimore to Equalizing Lagoon in Chesterfield Township			
Location of Line	Monroe to Treatment Plant	Port Huron to E. China Twp	E. China Twp. to Algonac	Algonac to New Baltimore	N. Baltimore to Chesterfield Twp
Exhibit Nos.	8	9	9	9	9
Total Length, Miles	11.1	16.2	10.6	13.3	6.1
Type of Line	Gravity	Gravity	Gravity	Gravity	Gravity
Diameter, Feet	7.5	5.0 & 6.0	6.5 & 7.0	7.5	7.5 & 8.0
Ave. Daily Flow, MGD	40	24	30	36	40
Peak Flow, MGD	70	42	52.5	63	70
No. of Pump Stations	4	4	None	2	2
Max. Pump H.P. Per Station	384	230	-	350	384
Ave. Pump H.P. Per Station	220	132	-	200	220

TABLE V-3

CONVEYANCE SYSTEM DESIGN SUMMARY

System Name	F		G	
Description	Tunnels in rock and interceptors from Red Run Area to St. Clair lagoon treatment site.		Interceptor along St. Clair Shoreline with transmission to St. Clair Irrigation area.	
Location of line	Red Run to St. Clair Lagoon Site	Warren to Red Run Interceptor	Algonac to St. Clair	St. Clair to Irrigation Site
Exhibit Numbers	10	10	11	11
Total Length Miles	22.0	2.3	14.8	12.8
Type of Line	Tunnel	Gravity	Gravity	Gravity
Diameter Feet	18.0	6.0	3.0	2.5 & 3.0
Ave. Daily Flow, MGD	600	36	6.0	6.0
Peak Flow, MGD	1050	63	10.5	10.5
No. of Pump Stations	1	None	5	8
Max. Pump H.P. per station	68,900	-	58	58
Ave. Pump H.P. per station	39,400	-	33	33

TABLE V-4

CONVEYANCE SYSTEM DESIGN SUMMARY

System Name	H	I	J
Description	Force Main from Monroe lagoon site to Fulton-Williams Irrigation site	Interceptor From Juncture of River Raisin to Lenawee Irrigation site	Force Main from Monroe lagoon site to Lenawee Irrigation site
Location of line	Monroe to Fulton-Williams site	Adrian-Tecumseh Corridor to Lewanee Irrigation Site	Monroe lagoon site to Lewanee Irrigation site
Exhibit Numbers	12	13	14
Total Length Miles	73.3	9.4	12.1
Type of Line	Force Main	Gravity & Force Main	Force Main
Diameter Feet	7.0,9.0,10.5,14.0&15.0	3.0, 3.5 & 4.5	4.0, 5.0 & 8.0
Ave. Daily Flow, MGD	129,206,301,507 & 860	12.0	33, 67 & 100
Peak Flow, MGD	129,206,301,507 & 860	21.0	33, 67 & 100
No. of Pump Stations	1	1 & 3	1
Max. Pump H.P. per station	97,700	281 & 115	4,100
Ave. Pump H.P. per station	97,700	161 & 66	4,100

TABLE V-5

CONVEYANCE SYSTEM DESIGN SUMMARY

System Name	K	L
Description	Force main from St. Clair lagoon treatment site to Huron-Tuscola irrigation site	Tunnel in rock (or interceptor in glacial drift) from Wyandotte to treatment plant at the mouth of the Huron R.
Location of line	St. Clair treatment site to Huron-Tuscola irrigation site	Wyandotte to Huron River treatment plant
Exhibit Numbers	15	16
Total Length Miles	98.3	16.8
Type of Line	Force Main	Tunnel
Diameter Feet	8, 9, 11, 11, 14, 15 & 16	10.0
Ave. Daily Flow, MGD	177, 244, 333, 355, 599, 777&1110	125
Peak Flow, MGD	177, 244, 333, 355, 599, 777&1110	219
No. of Pump Stations	1	1
Max. Pump H.P. per station	108,100	8,200
Ave. Pump H. P. per station	108,100	4,700

TABLE V-6

CONVEYANCE SYSTEM DESIGN SUMMARY

System Name	M	N	
Description	Tunnel in rock (or interceptor in glacial drift) from Detroit to lagoon treatment site	Interceptors from Tecumseh and Adrian to proposed treatment plant at Juncture of River Raisin and South Branch of River Raisin	
Location of Line	Detroit to Monroe lagoon treatment site	Adrian to treatment plant	Tecumseh to treatment plant
Exhibit Numbers	17	18	18
Total Length Miles	48.3	2.0	6.4
Type of Line	Tunnel	Gravity	Gravity
Diameter Feet	22.0	3.0	3.0
Ave. Daily Flow, MGD	930	6.0	6.0
Peak Flow, MGD	1630	10.5	10.5
No. of Pump Stations	1	1	NONE
Max. Pump H.P. per station	119,800	35	-
Ave. Pump H.P. per station	68,400	20	-

alternatives. Each alternative design consists of a specific set of pipe diameters, their associated head losses, and pumping station requirements. These combinations are evaluated by calculating the force main and pumping station annual costs for each alternative and selecting the design with the lowest overall annual cost as being optimal for the system.

Costs

Tables V-7 through V-13 give the cost summaries for the conveyance systems discussed in this section. Unit costs and more detailed information on conveyance systems may be found in the Appendix.

Performance and Reliability

The gravity interceptor and force main conveyance systems are expected to perform with the reliability that is typically associated with each type of system. The performance and reliability of the tunnel systems is discussed in some detail in other sections of this report.

TABLE V-7

COST SUMMARY FOR CONVEYANCE SYSTEMS

	System A	System B
Capital Cost		
Interceptors	$ 4,740,000	$ 9,570,000
Pump Stations	1,536,000	2,580,000
Subtotal	6,276,000	12,150,000
10% Engineering	628,000	1,215,000
5% Administration	314,000	608,000
10% Contingencies	628,000	1,215,000
Total	$ 7,846,000	$ 15,188,000
Annual Capital Cost		
@ 5-1/2%	463,400	897,000
@ 7%	568,500	1,101,000
@ 10%	791,300	1,532,000
Operation & Maintenance/Year		
Power	$ 12,900	$ 34,600
Labor (includes 25% overhead)	24,800	44,900
Materials & Supplies	12,400	22,500
Total	$ 50,100	$ 102,000
Replacement Cost -Pumping Stations		
20% of Capital Cost @ 25 Years	307,000	516,000
15% of Capital Cost @ 10 Years	230,000	387,000
Annual Replacement Cost		
@ 5-1/2%	21,600	36,300
@ 7%	20,200	34,000
@ 10%	17,100	28,700
Total Annual Cost		
@ 5-1/2%	$ 535,100	$ 1,035,300
@ 7%	$ 638,800	$ 1,237,000
@ 10%	$ 858,500	$ 1,662,700

TABLE V-8

COST SUMMARY FOR CONVEYANCE SYSTEMS

	System C	System D
Capital Cost		
Tunnel	$ 70,080,000	
Interceptors		$ 8,340,000
Pump Stations	21,140,000	3,840,000
Subtotal	91,220,000	12,180,000
10% Engineering	9,122,000	1,218,000
5% Administrative	4,561,000	609,000
10% Contingencies	9,122,000	1,218,000
Total	$ 114,025,000	$ 15,225,000
Annual Capital Cost		
@ 5-1/2%	6,734,000	899,200
@ 7%	8,262,000	1,103,200
@ 10%	11,501,000	1,535,600
Operation & Maintenance/Year		
Power	$ 3,070,000	$ 57,500
Labor (includes 25% overhead)	349,300	55,100
Materials & Supplies	174,600	27,500
Total	$ 3,593,900	$ 140,100
Replacement Cost-Pumping Station		
20% of Capital Cost @ 25 Years	4,228,000	768,000
15% of Capital Cost @ 10 Years	3,171,000	576,000
Annual Replacement Cost		
@ 5-1/2%	297,700	54,100
@ 7%	278,200	50,500
@ 10%	235,500	42,800
Total Annual Cost		
@ 5-1/2%	$ 10,625,600	$ 1,093,400
@ 7%	$ 12,134,100	$ 1,293,800
@ 10%	$ 15,330,400	$ 1,718.500

TABLE V-9

COST SUMMARY FOR CONVEYANCE SYSTEMS

	System E	System F
Capital Cost		
Tunnel		$ 54,850,000
Interceptors	$ 30,458,000	1,410,000
Pump Stations	6,248,000	16,650,000
Subtotal	36,706,000	72,910,000
10% Engineering	3,671,000	7,291,000
5% Administrative	1,836,000	3,646,000
10% Contingencies	3,671,000	7,291,000
Total	$ 45,884,000	$ 91,138,000
Annual Capital Cost		
@ 5-1/2%	2,709,900	5,382,600
@ 7%	3,324,800	6,603,900
@ 10%	4,627,900	9,192,200
Operation & Maintenance/Year		
Power	$ 89,100	$ 2,570,000
Labor (includes 25% overhead)	123,400	276,500
Materials & Supplies	61,700	138,300
Total	$ 274,200	$ 2,984,800
Replacement Cost-Pumping Station		
20% of Capital Cost @ 25 years	1,250,000	3,330,000
15% of Capital Cost @ 10 years	937,000	2,498,000
Annual Replacement Cost		
@ 5-1/2%	88,000	234,400
@ 7%	82,200	219,100
@ 10%	69,600	185,500
Total Annual Cost		
@ 5-1/2%	$ 3,072,100	$ 8,601,800
@ 7%	$ 3,681,200	$ 9,807,800
@ 10%	$ 4,971,700	$ 12,362,500

TABLE V-10

COST SUMMARY FOR CONVEYANCE SYSTEMS

	System G	System H
Capital Cost		
Force Main	-	$ 93,591,000
Interceptors	$ 8,292,000	-
Pump Stations	3,328,000	18,633,000
Sub Total	11,620,000	112,224,000
10% Engineering	1,162,000	11,222,400
5% Administrative	581,000	5,611,200
10% Contingencies	1,162,000	11,222,400
Total	$ 14,525,000	$ 140,280,000
Annual Capital Cost		
@ 5-1/2%	857,800	8,284,900
@ 7%	1,052,500	10,164,700
@ 10%	1,465,000	14,148,600
Operation & Maintenance/Year		
Power	$ 28,000	$ 6,382,000
Labor (includes 25% overhead)	49,900	373,500
Materials & Supplies	24,900	186,800
Total	$ 102,800	$ 6,942,300
Replacement Cost - Pumping Station		
20% of Capital Cost @ 25 years	665,600	3,726,600
15% of Capital Cost @ 10 years	499,200	2,795,000
Annual Replacement Cost		
@ 5-1/2%	46,900	262,400
@ 7%	43,800	245,200
@ 10%	37,100	207,600
Total Annual Cost		
@ 5-1/2%	$ 1,007,500	$ 15,489,600
@ 7%	$ 1,199,100	$ 17,352,200
@ 10%	$ 1,604,900	$ 21,298,500

TABLE V-11

COST SUMMARY FOR CONVEYANCE SYSTEMS

	System I	System J
Capital Cost		
Force Main	$ -	$ 7,081,000
Interceptors	$ 3,570,000	-
Pump Stations	1,600,000	1,548,000
Sub Total	5,170,000	8,629,000
10% Engineering	517,000	862,900
5% Administrative	258,500	431,500
10% Contingencies	517,000	862,900
Total	$ 6,462,500	$ 10,786,300
Annual Capital Cost		
@ 5-1/2%	381,700	637,000
@ 7%	468,300	781,600
@ 10%	651,800	1,087,900
Operation & Maintenance/Year		
Power	$ 23,400	$ 268,000
Labor (includes 25% overhead)	23,100	29,700
Materials & Supplies	11,600	14,900
Total	$ 58,100	$ 312,600
Replacement Cost - Pumping Station		
20% of Capital Cost @ 25 years	320,000	309,600
15% of Capital Cost @ 10 years	240,000	232,200
Annual Replacement Cost		
@ 5-1/2%	22,500	21,800
@ 7%	21,100	20,400
@ 10%	17,800	17,200
Total Annual Cost		
@ 5-1/2%	$ 462,300	$ 971,400
@ 7%	$ 547,500	$ 1,114,600
@ 10%	$ 727,700	$ 1,417,700

TABLE V-12

COST SUMMARY FOR CONVEYANCE SYSTEMS

	System K	System L
Capital Cost		
Tunnel	-	$ 20,836,000
Force Main	$ 128,489,000	-
Pump Stations	21,873,000	2,630,000
Sub Total	150,362,000	23,466,000
10% Engineering	15,036,200	2,346,600
5% Administrative	7,518,100	1,173,300
10% Contingencies	15,036,200	2,346,600
Total	$ 187,952,500	$ 29,332,500
Annual Capital Cost		
@ 5-1/2%	11,100,500	1,732,400
@ 7%	13,619,000	2,125,400
@ 10%	18,956,700	2,958,500
Operation & Maintenance/Year		
Power	$ 7,063,000	$ 306,400
Labor (includes 25% overhead)	475,700	67,300
Materials & Supplies	237,900	33,700
Total	$ 7,776,600	$ 407,400
Replacement Cost - Pumping Station		
20% of Capital Cost @25 years	4,374,600	526,000
15% of Capital Cost @10 years	3,281,000	394,500
Annual Replacement Cost		
@ 5-1/2%	308,000	37,000
@ 7%	287,800	34,600
@ 10%	243,700	29,300
Total Annual Cost		
@ 5-1/2%	$ 19,185,100	$ 2,176,800
@ 7%	$ 21,683,400	$ 2,567,400
@ 10%	$ 26,977,000	$ 3,395,200

TABLE V-13

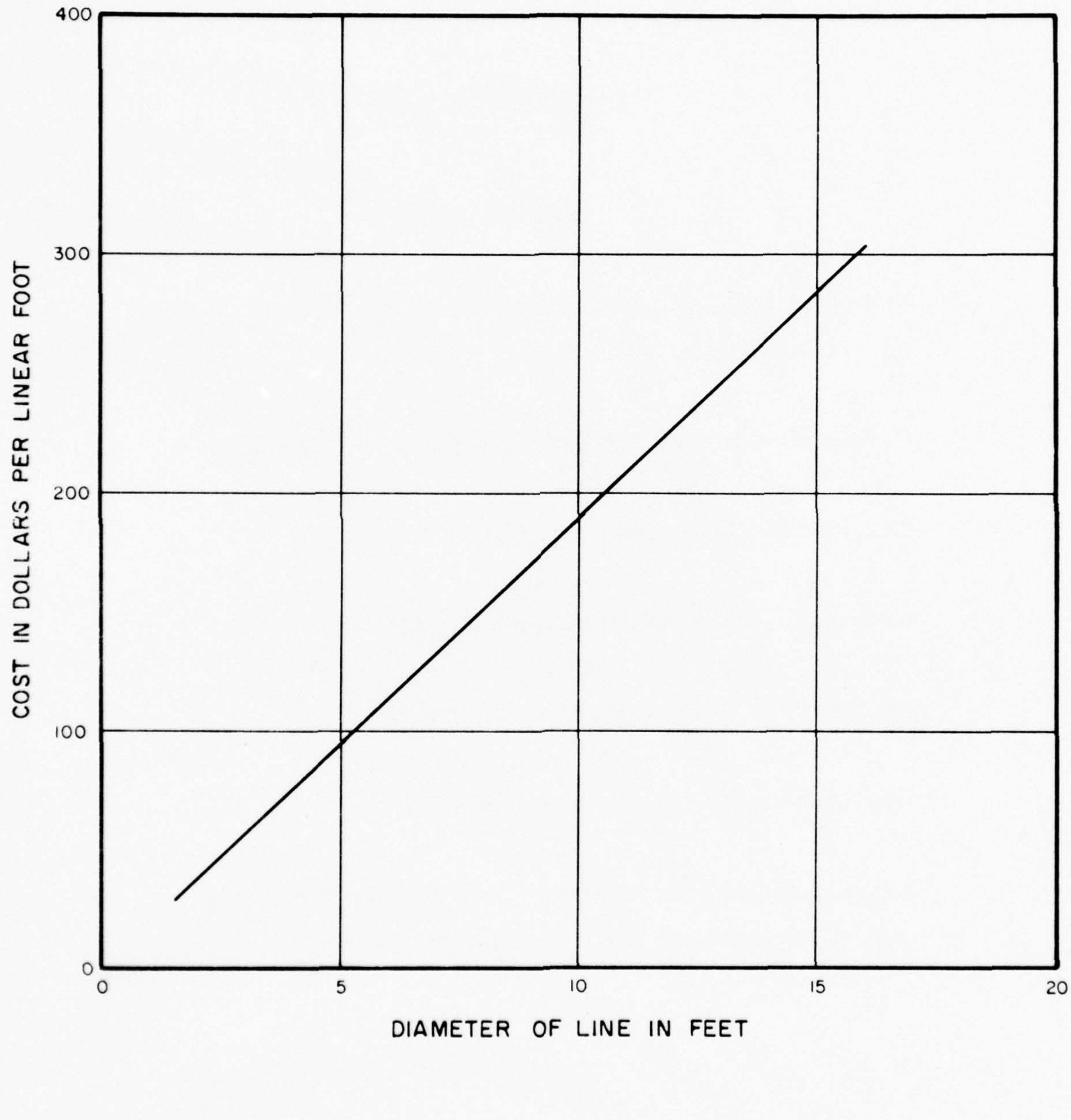
COST SUMMARY FOR CONVEYANCE SYSTEMS

	System M	System N
Capital Cost		
Tunnel	$ 156,800,000	-
Force Main	-	$ 2,546,000
Pump Stations	27,415,000	256,000
Sub Total	184,215,000	2,802,000
10% Engineering	18,421,500	280,200
5% Administrative	9,210,800	140,100
10% Contingencies	18,421,500	280,200
Total	$ 230,268,800	$ 3,502,500
Annual Capital Cost		
@ 5-1/2%	13,599,700	206,900
@ 7%	16,685,300	253,800
@ 10%	23,224,900	353,300
Operation & Maintenance/Year		
Power	$ 4,465,000	$ 1,300
Labor (includes 25% overhead)	585,200	8,100
Materials & Supplies	292,600	4,100
Total	$ 5,342,800	$ 13,500
Replacement Cost - Pumping Station		
20% of Capital Cost @25 years	5,483,000	51,200
15% of Capital Cost @10 years	4,112,300	38,400
Annual Replacement Cost		
@ 5-1/2%	386,000	3,600
@ 7%	360,800	3,400
@ 10%	305,400	2,900
Total Annual Cost		
@ 5-1/2%	$ 19,328,500	$ 224,000
@ 7%	$ 22,388,900	$ 270,700
@ 10%	$ 28,873,100	$ 369,700

APPENDIX

CONVEYANCE SYSTEM

LIST OF ITEMS



ESTIMATED AVERAGE CONSTRUCTION COSTS
FOR GRAVITY SEWERS & FORCE MAINS

CONVEYANCE TUNNEL CONSTRUCTION COSTS

Chicago Experience

Three tunnels in strong dolomite formations beneath the Chicago area have been constructed over the past few years. These are:

1. Lawrence Avenue Tunnel, 5.5 miles long, upper diameter 12 feet, lower diameter 17 feet, cost about $10 million, including allowance for concrete lining.

2. Crawford Avenue Tunnel, 3.5 miles long, diameter about 16 feet, cost about $7.5 million including concrete lining.

3. Forty-seventh Street Tunnel, 3.5 miles long, diameter about 16 feet, cost about $7.5 million including concrete lining.

All three of these tunnels were let by competitive bidding with construction to include concrete lining. After experience with the "mole" construction it was decided to eliminate the concrete lining as the bored hole proved to be smooth and strong. Both hydraulic capacity and storage capacity would have been reduced by the concrete lining. Infiltration into the tunnel was found to be controllable through grouting at selected locations, and roof spalling was found to be almost non-existent.

Future tunnels of this type will be advertised for construction without concrete lining, as it is obviously less expensive. Further improvements in materials handling will probably reduce "mole" construction cost even further. Three different manufacturers of "moles" were involved in the three tunnels constructed so far, with others being involved in the bidding.

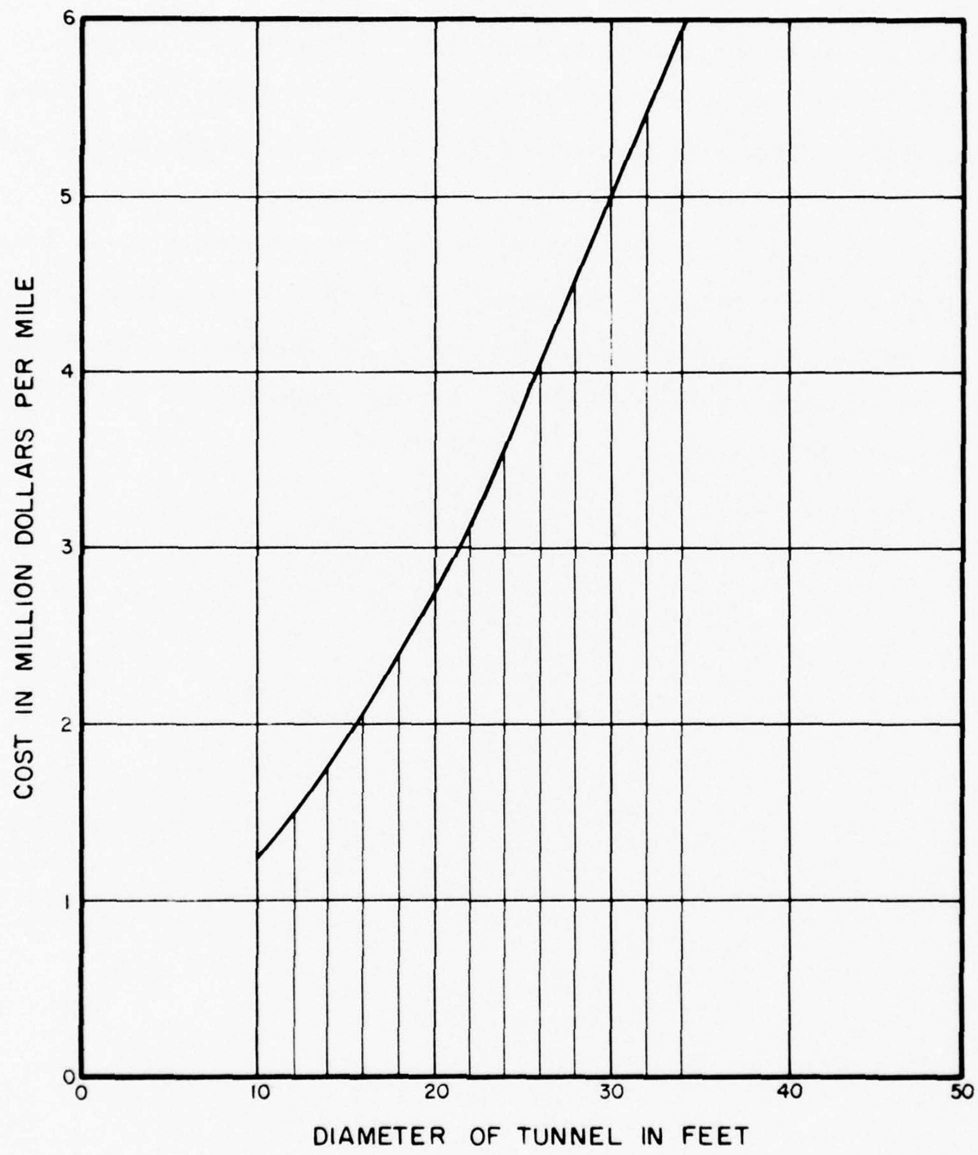
Other U.S. Cities

Rock suitable to economical "mole" tunnel construction is widespread throughout the Chicago region. Both the Silurian and Galena-Platteville dolomites are well suited to this type of construction. Similar rock formations exist throughout the Great Lakes region. Other formations also well suited for "mole" tunnel constructions are located under other large cities, Washington, D. C. being one example. It is likely that tunnels would also be economical under still other U.S. cities where rock conditions are not so well suited to "mole" tunnel construction.

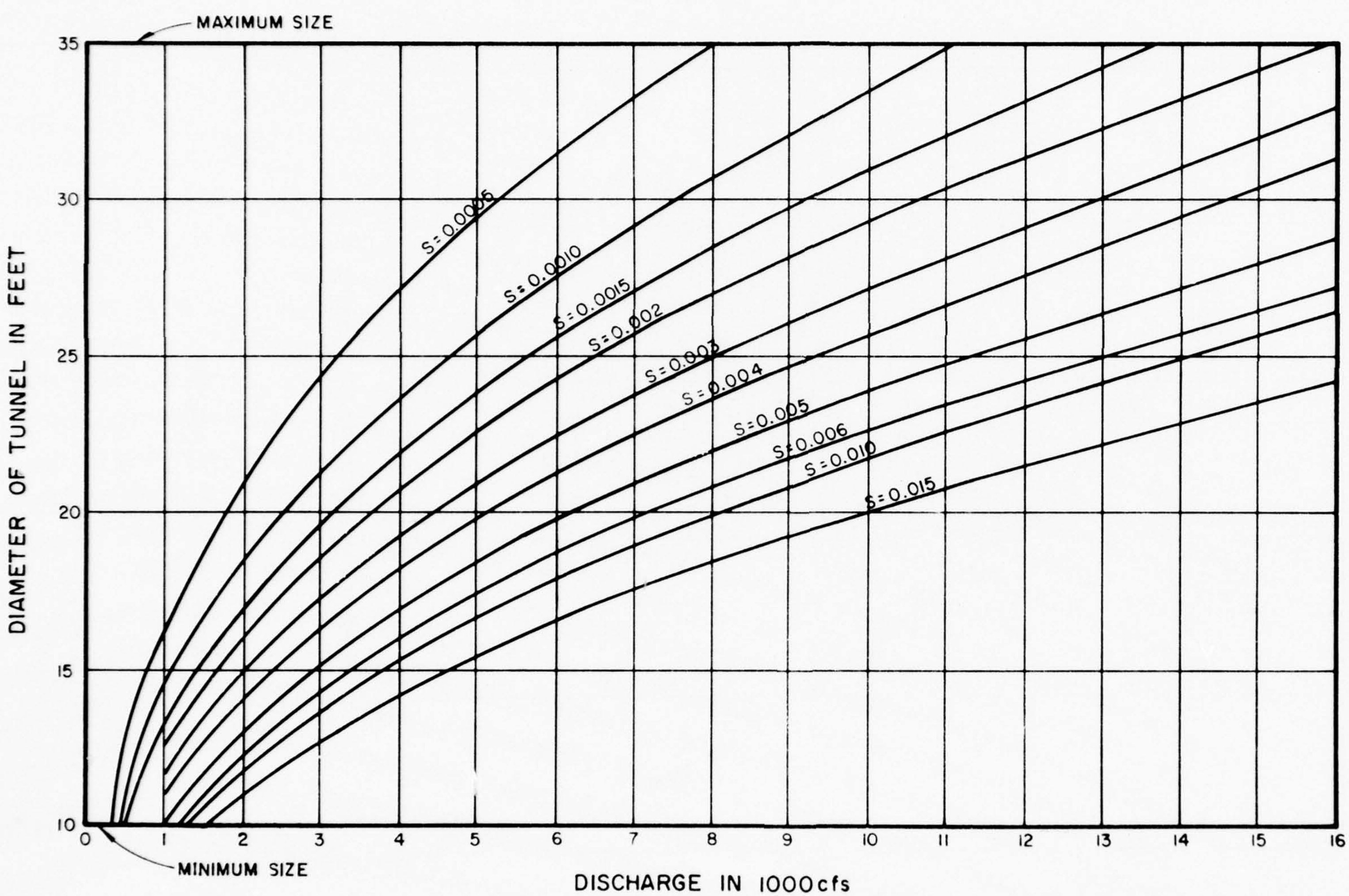
No doubt large-scale use of "mole" tunnel construction for regional wastewater systems in large mtropolitan areas would stimulate improvements in "moles" and associated materials handling systems. At present, the design of bits has progressed rather far so that the usual limit on construction progress is not

the actual boring operation but rather the ability to remove the rock chips from the face. Such a problem appears to be susceptible to solution through materials handling engineering.

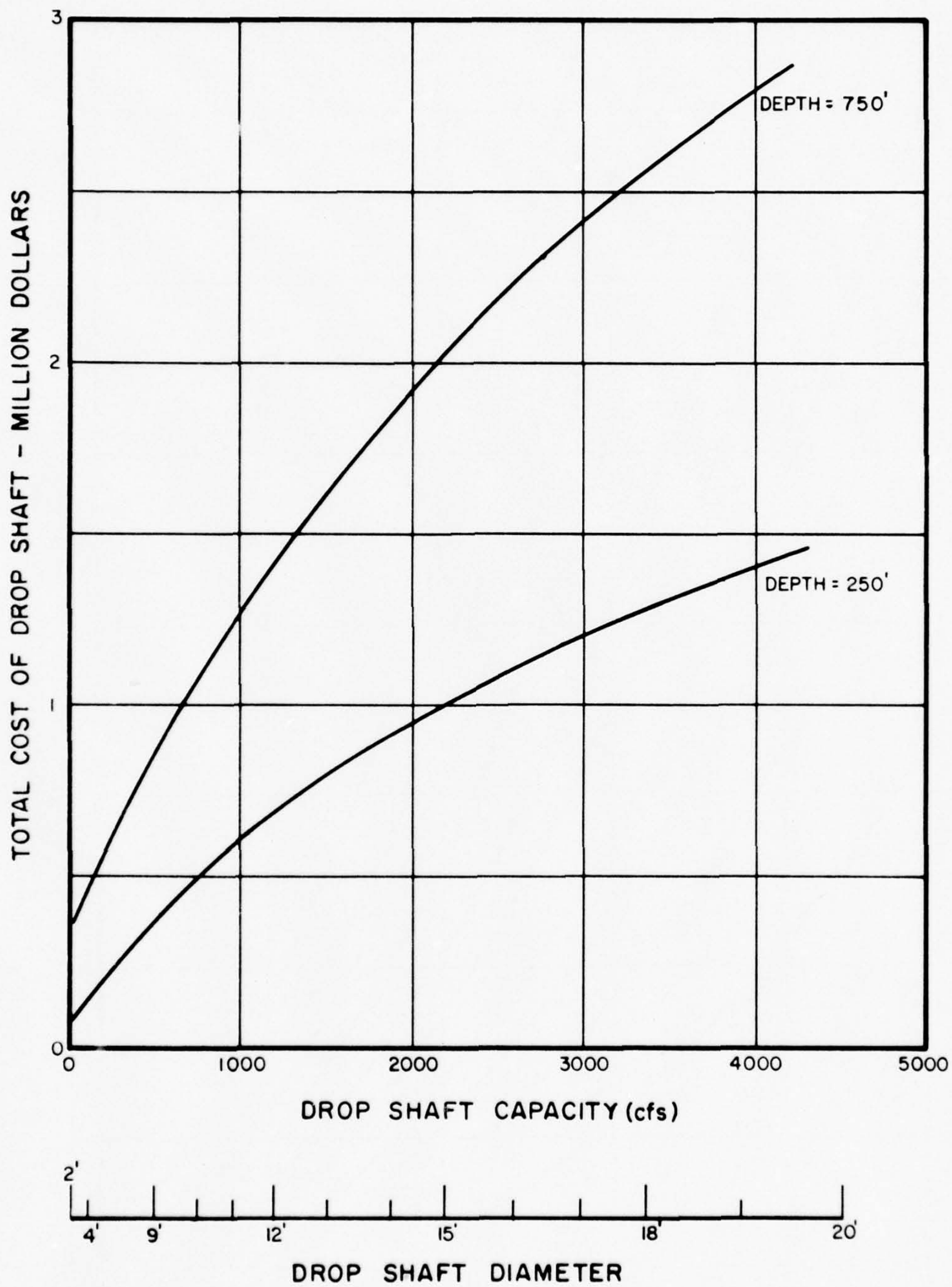
Present costs for unlined "mole" bored tunnels range from \$200 per foot for a 10' diameter, and \$300 per foot for a 16' diameter, up to \$1,000 per foot for a 35' diameter. These figures correspond to \$1.50/cu.ft. for 16' diameter and \$1.00/cu. ft. for 35' diameter.



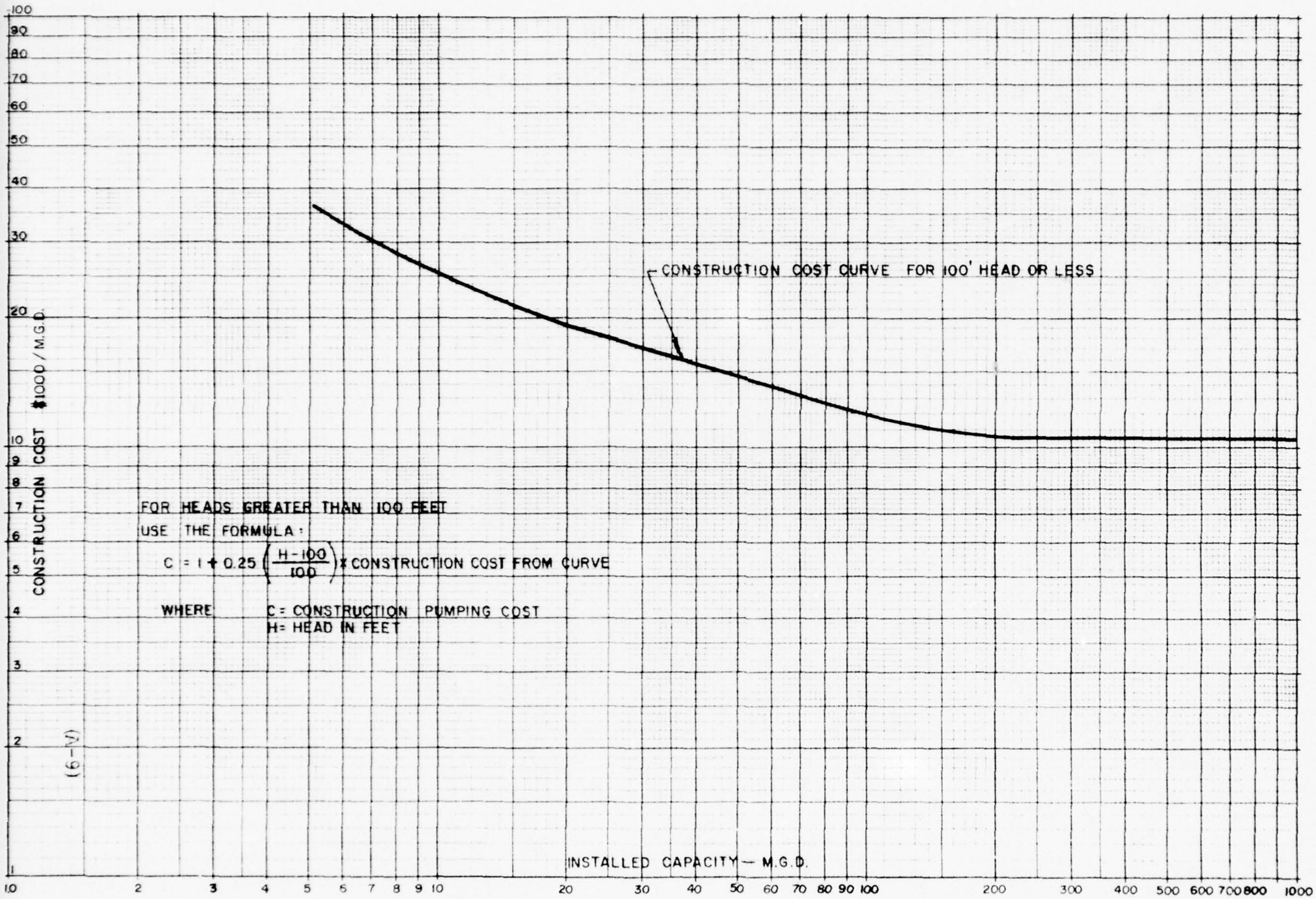
COST CURVE FOR UNLINED MOLE TUNNEL



CURVES FOR SIZING UNLINED MOLE TUNNELS
(n = 0.017)



ESTIMATED COST — DROP SHAFT



PUMPING STATION CONSTRUCTION COSTS

PUMPING STATION REPLACEMENT COST PRESENT WORTH AND ANNUAL REPLACEMENT COST MULTIPLYING FACTORS

Components	% of Total Cost	Replacement Required in Years
Land & Struct.	60%	None in 50 years
	20%	Every 25 years
Mechanical	10%	Every 10 years
Other	5%	Every 10 years
	5%	None in 50 years

For 5-1/2% Interest Rate:

@ 25 years	0.20 x 0.2622 =	0.05244
@ 10 years	0.15 x 1.2400 =	0.18600
		0.23844

Present Worth = 0.23844 x Capital Cost

Annual Replacement Cost = 0.23844 x 0.05906 x Capital Cost
= 0.01408 x Capital Cost

For 7% Interest Rate:

@ 25 years	0.20 x 0.1842 =	0.03684
@ 10 years	0.15 x 0.9647 =	0.144735
		0.181575

Present Worth = 0.18158 x Capital Cost

Annual Replacement Cost = 0.18158 x 0.07246 x Capital Cost
= 0.01316 x Capital Cost

For 10% Interest Rate:

@ 25 years	0.20 x 0.0923 =	0.01846
@ 10 years	0.15 x 0.6135 =	0.092025
		0.110485

Present Worth = 0.11049 x Capital Cost

Annual Replacement Cost = 0.11049 x 0.10086 x Capital Cost
= 0.01114 x Capital Cost

SLUDGE MANAGEMENT

LIST OF ITEMS

CAPITAL COST SUMMARY FOR SLUDGE MANAGEMENT
ST. CLAIR TREATMENT SITE

Component	Quantity-Unit	Unit Cost	Cost
Underdrain System	13 modules	$1,632,600/module	$21,223,800
Sludge Spreading Equipment	10 units	371,800/unit	3,718,000
TRANSMISSION SYSTEM FROM SOUTH SITE TO NORTH SITE			
1-Main Pump Station	1,059 HP	$150/HP	$ 158,900
3-Secondary Pump Stations	1,250 HP	250/HP	312,500
36" Transmission Pipe	39,600 lin.ft.	54/lin.ft.	2,138,400
24" Transmission Pipe	71,280 lin.ft.	36/lin.ft.	2,566,100
18" Transmission Pipe	23,760 lin.ft.	27/lin.ft.	641,500
Total Transmission System			$ 5,817,400
SLUDGE DISTRIBUTION SYSTEM			
8-Sludge Pump Stations	2,170 HP	$250/HP	$ 542,500
36" Distribution Pipe	18,480 lin.ft.	54/lin.ft.	997,900
30" Distribution Pipe	9,240 lin.ft.	45/lin.ft.	415,800
20" Distribution Pipe	9,240 lin.ft.	30/lin.ft.	277,200
16" Distribution Pipe	60 miles	24/lin.ft.	7,603,200

CAPITAL COST SUMMARY FOR SUDGE MANAGEMENT (Cont.)
ST. CLAIR TREATMENT SITE

Component	Quantity-Unit	Unit Cost	Cost
SLUDGE DISTRIBUTION SYSTEM (cont.)			
Fittings (10% of Pipe Cost)			$ 706,100
Total Distribution System			$10,542,700
Land	33,289 acres	$751/acre	25,000,000
Total Sludge Management System			$66,301,900

CAPITAL COST SUMMARY FOR SLUDGE MANAGEMENT
MONROE TREATMENT SITE

Component	Quantity-Unit	Unit Cost	Cost
Underdrain System	4 modules	$1,632,600/module	$6,530,400
Sludge Spreading Equipment	3 Units	371,800/unit	1,115,400
SLUDGE DISTRIBUTION SYSTEM			
3-Sludge Pump Stations	780 HP	$250/HP	$ 195,000
16" Distribution Pipe	28 miles	24/lin.ft.	3,548,200
Fittings (10% of Pipe Cost)	L.S.		354,800
Total Distribution System			$4,098,000
Land	9,720 acres	$1358/acre	13,200,000
Total Sludge Management System			$24,943,800

SLUDGE MANAGEMENT O & M COSTS
ST. CLAIR TREATMENT SITE

LABOR REQUIREMENTS		
Sludge Spreading-10 Units @ 10 Men/Unit= 100 Men		
	100 Men @ $13,200	$1,320,000
	+ 25% Overhead	329,000
	Total	$1,649,000
Sludge Distribution		
	18 Men @ $13,200	237,000
	+ 25% Overhead	59,000
	Total	$ 296,000
Transmission System from South Site to North Site		
	7 Men @ $13,200	92,000
	+ 25% Overhead	23,000
	Total	$ 115,000
Total Labor Costs		$2,060,000
POWER COSTS @ $0.01/KW-HR		
Sludge Spreading Pumps-320HP-1600 Hrs.		$ 3,800
Distribution Pumps - 670HP-1600 Hrs.		8,000
Transmission Pumps - 1500HP-1600 Hrs.		17,900
Total Power Cost		$ 29,700
MATERIALS & SUPPLIES		
Sludge Spreading @ 10% Capital Cost		$ 372,000
Sludge Distribution @ 5% Capital Cost		527,000
Sludge Transmission @ 2.5% Capital Cost		146,000
Total Materials & Supplies Cost		$1,050,000

SLUDGE MANAGEMENT O & M COSTS
MONROE TREATMENT SITE

LABOR REQUIREMENTS		
Sludge Spreading-3 Units @ 10 Men/Unit= 30 Men		
	30 Men @ $13,200	$396,000
	+ 25% Overhead	99,000
	Total	$495,000
Sludge Distribution		
	7.5 Men @ $13,200	99,000
	+ 25% Overhead	25,000
	Total	$124,000
Total Labor Costs		$620,000
POWER COSTS @ $0.01/KW-HR.		
Sludge Spreading Pumps- 96HP-1600 Hrs.		$ 1,100
Distribution Pumps - 612HP-1600 Hrs.		7,300
Total Power Cost		$ 8,400
MATERIALS & SUPPLIES		
Sludge Spreading @ 10% Capital Cost		$111,000
Sludge Distribution @ 5% Capital Cost		204,000
Total Materials & Supplies Cost		$315,000

SLUDGE MANAGEMENT

Capital Cost Sludge Spreading Unit

Components	Quantity-Unit	Unit-Cost	Cost
Dredge	1	$200,000	$200,000
Dredge Connection Pipe	2	20,000	40,000
Surge Tank	1	10,000	10,000
Transport Pipe	18,000 lin.ft.	$3.11/lin.ft.	56,000
Permanent Pump Sta.	1	8,000	8,000
Temporary Pump Sta.	4	3,000	12,000
Flexible Hose	1	4,800	4,800
Tractor	1	25,000	25,000
Mohlboard Plow	1	6,000	6,000
Truck	1	5,000	5,000
Communication Equipment	1	5,000	5,000
Total Unit Cost			$371,800

SLUDGE MANAGEMENT

Capital Cost Underdrain Module

Components	Quantities-Unit	Unit-Cost	Cost
Drainage Pipe			
4" Plastic	3,163,000 LF	0.31	$980,500
12" RCP	6,000 LF	5.54	33,200
15" RCP	4,560 LF	7.08	33,300
18" RCP	8,400 LF	9.51	79,900
21" RCP	12,000 LF	10.76	129,100
24" RCP	10,650 LF	13.32	141,900
30" RCP	2,640 LF	18.23	48,100
36" RCP	2,640 LF	24.74	65,300
48" RCP	2,640 LF	36.95	97,500
Clean-outs			
4 ft dia.	40 ea	521	20,800
5 ft dia.	3 ea	1000	3,000
Underdrain Module Total			$1,632,600

LAGOON TREATMENT SYSTEM

LIST OF ITEMS

CAPITAL COST SUMMARY FOR LAGOON TREATMENT SYSTEM
ST. CLAIR TREATMENT SITE

Component	Quantity-Unit	Unit Cost	Cost
EQUALIZATION LAGOONS			
Earthwork	2 @ 3,567,000 c.y.	\$ 0.81/c.y.	\$ 5,778,000
Lining			
8" Soil Cement	2 @ 221,900 s.y.	\$ 2.33/s.y.	1,034,000
8" Clay	2 @ 717,600 s.y.	0.45/s.y.	646,000
Roadway-Gravel	105,400 s.y.	2.20/s.y.	232,000
Flow Structure	1,005 c.y.	175/c.y.	176,000
Service Bldg.	1,600 $ft.^2$	20/$ft.^2$	32,000
Land	2,000 acres	3000/acre	6,000,000
Total Equalization Lagoon System			\$13,898,000
WASTEWATER CONVEYANCE SYSTEM			
Wastewater Tunnel	25.28 miles	\$3,370,000/mile	\$85,207,000
Drop Shafts	L.S.		2,190,000
Wastewater Pumping Station	1	\$35,412,000/unit	35,412,000
Total Wastewater Conveyance System			\$122,809,000
GRIT REMOVAL			
(Municipal & Industrial Wastewater)			
Grit Chambers	32	\$ 70,050/unit	\$ 2,452,000
Grit Removal Equipment	32	13,000/unit	416,000
Grit Loading Equipment	1	40,000/unit	40,000
Truck - Dump	3	25,000/unit	75,000
Bulldozer	1	25,000/unit	25,000
Land	50 acres	751/acre	37,600
(Stormwater)			
Earthwork	180,000 c.y.	\$ 0.81/c.y.	143,800
Overflow Weir	3,000 c.y.	175/c.y.	525,000

CAPITAL COST SUMMARY FOR LAGOON TREATMENT SYSTEM (Cont.)
ST. CLAIR TREATMENT SITE

Component	Quantity-Unit	Unit Cost	Cost
GRIT REMOVAL (cont.)			
(Stormwater)			
Grit Removal Equipment	1	$200,000/unit	$ 200,000
Truck - Dump	2	25,000/truck	50,000
Bulldozer	1	25,000/unit	25,000
SCREENING			
(Municipal & Industrial)			
Structure	16	$52,800/unit	$ 844,800
Equipment	16	40,000/unit	640,000
(Stormwater)			
Structure	134	$52,800/unit	7,075,000
Equipment	134	40,000/unit	5,360,000
Total Grit Removal and Screening System			$17,909,200
AERATED LAGOONS			
Earthwork	9,480,000 c.y.	$ 0.81/c.y.	7,678,600
Lining			
6" Concrete			
Wave Protection	125,500 c.y.	$ 80/c.y.	10,044,000
8" Soil Cement	722,250 s.y.	2.33/s.y.	1,683,000
12" Clay Lining	5,880,600 s.y.	0.68/s.y.	3,998,400
Roadway			
20' - Bituminous	284,300 s.y.	$ 6.50/s.y.	1,848,000
Flumes	72,271 c.y.	175/c.y.	12,647,000
Aerators - 150HP	972 Each	35,000/unit	34,020,000

CAPITAL COST SUMMARY FOR LAGOON TREATMENT SYSTEM (Cont.)
ST. CLAIR TREATMENT SITE

Component	Quantity-Unit	Unit Cost	Cost
AERATED LAGOONS (Cont.)			
Electrical Equipment	L.S.		$ 5,832,000
Land	1,540 acres	$ 751/acre	1,156,500
Total Aerated Lagoon System			$78,907,500
STORAGE LAGOONS			
Earthwork	116,856,000 c.y.	$ 0.81/c.y.	$94,655,000
Lining			
8" Soil Cement	13,500,000 s.y.	$ 2.33/s.y.	31,455,000
8" Clay Lining	11,147,000 s.y.	0.45/s.y.	5,016,000
Roadway-Gravel	1,669,400 s.y.	2.20/s.y.	3,673,000
Interconnecting Structures	38 units	86,500/unit	3,287,000
Outlet Structure With Chlorination Facilities	13 units	291,400/unit	3,788,000
Chlorination Bldg.	7	250,000/bldg.	1,750,000
Conveyance System Between Lagoons	81,840 lin.ft.	305/lin.ft.	24,961,000
Land	54,000 acres	751/acre	40,554,000
Total Storage Lagoon System			$209,139,000
SEEPAGE CONTROL			
Drainage Channel	3,493,500 c.y.	$ 0.81/c.y.	2,829,750
Drainage Pump Stations	14	42,000/p.s.	588,000
Observation Wells			
1-1/4" Casing	13,800 ft.	3.50/ft.	48,300
Development	746 hrs.	25/hr.	18,650
Plunger Cylinders	138 each	140/cyl.	19,300
Total Seepage Control System			$ 3,504,000

CAPITAL COST SUMMARY FOR LAGOON TREATMENT SYSTEM (Cont.)
ST. CLAIR TREATMENT SITE

Component	Quantity-Unit	Unit Cost	Cost
SLUDGE MANAGEMENT	L.S.		$66,301,900
RENOVATED WATER CONVEYANCE SYSTEM			
Renovated Water Tunnel	10.9 miles	$2,800,000/mile	$30,545,500
Drop Shafts	L.S.		1,324,000
Open Channel	4,741,600 c.y.	0.81/c.y.	3,841,000
Total Renovated Water Conveyance System			$35,710,500

CAPITAL COST SUMMARY FOR LAGOON TREATMENT SYSTEM
MONROE TREATMENT SITE

Component	Quantity-Units	Unit Cost	Cost
EQUALIZATION LAGOONS			
Earthwork	2 @3,567,000 c.y.	$ 0.81/c.y.	$ 5,778,000
Lining -			
8" Soil Cement	2 @ 221,900 s.y.	2.33/s.y.	1,034,000
8" Clay	2 @ 717,600 s.y.	0.45/s.y.	646,000
Roadway-Gravel	105,400 s.y.	2.20/s.y.	232,000
Flow Structure	1,005 c.y.	175/c.y.	176,000
Service Building	1,600 ft^2	20/ft^2	32,000
Land	2,000 acres	2,000/acre	4,000,000
Total Equalization Lagoon System			$11,898,000
WASTEWATER CONVEYANCE SYSTEM			
Wastewater Tunnel	23.63 miles	$ 2,440,000 miles	$57,650,000
Drop Shafts	L.S.		1,640,000
Pump Station	1	28,874,000	28,874,000
Total Wastewater Conveyance System			$88,164,000
GRIT REMOVAL (Municipal & Industrial Wastes)			
Grit Chambers	17 units	$ 70,050/unit	$ 1,190,800
Grit Removal Equipment	17 units	13,000/unit	221,000
Grit Loading Equipment	1 unit	40,000/unit	40,000
Truck-Dump	1	25,000	25,000
Bulldozer	1	25,000	25,000
Land	30.4 acres	1,358/acre	41,300

CAPITAL COST SUMMARY FOR LAGOON TREATMENT SYSTEM (Cont.)
MONROE TREATMENT SITE

Component	Quantity-Unit	Unit Cost	Cost
GRIT REMOVAL (Cont.)			
(Stormwater)			
Earthwork	141,600 c.y.	$ 0.81/c.y.	$ 114,700
Overflow Weir	2,420 c.y.	175/ c.y.	423,500
Grit Removal Equipment	1 unit	200,000/unit	200,000
Truck-Dump	2	25,000	50,000
Bulldozer	1	25,000	25,000
SCREENING			
(Municipal & Industrial Wastes)			
Structure	5 units	$ 52,800/unit	$ 264,000
Equipment	5 units	40,000/unit	200,000
(Stormwater)			
Structure	85 units	$ 52,800/unit	$ 4,488,000
Equipment	85 units	40,000/unit	3,400,000
Total Grit Removal & Screening System			$10,708,300
AERATED LAGOONS			
Earthwork	5,969,000 c.y.	$ 0.81/c.y.	$ 4,835,000
Lining -			
6" Concrete Wave Protection	72,525 c.y.	80/c.y.	5,806,000
8" Soil Cement	454,750 s.y.	2.33/ s.y.	1,060,000
12" Clay Lining	3,502,600 s.y.	2.00/s.y.	7,005,000

CAPITAL COST SUMMARY FOR LAGOON TREATMENT SYSTEM (Cont.)
MONROE TREATMENT SITE

Component	Quantity-Unit	Unit Cost	Cost
AERATED LAGOONS (Cont.)			
Roadway			
20'-Bituminous	179,000 s.y.	$ 6.50/s.y.	$ 1,163,500
Flumes	32,400 c.y.	175/c.y.	5,700,000
Aerators - 150 HP	612	35,000	21,420,000
Electrical Equipment	L.S.		3,672,000
Land	984 acres	1,358/acres	1,336,700
Total Aerated Lagoon System			$51,998,200
STORAGE LAGOONS			
Earthwork	73,576,000 c.y.	$ 0.81/c.y.	$59,600,000
Lining -			
8" Soil Cement	8,500,000 s.y.	2.33/s.y.	19,805,000
8" Clay Lining	13,493,000 s.y.	2.00/s.y.	26,986,000
Roadway-20' Wide Gravel	1,051,000 s.y.	2.20/s.y.	2,312,500
Interconnecting Structures	22 units	86,500/unit	1,903,000
Outlet Structure w/Chlorination Facilities	9 units	291,400/unit	2,622,600
Chlorination Building	5 Bldgs.	250,000	1,250,000
Conveyance System between Lagoons	2,600 lin.ft.	305/lin.ft.	793,000
Land	34,500 acres	1,358/acres	46,852,000
Total Storage Lagoon System			$162,124,000

CAPITAL COST SUMMARY FOR LAGOON TREATMENT SYSTEM (Cont.)
MONROE TREATMENT SITE

Component	Quantity-Unit	Unit Cost	Cost
SEEPAGE CONTROL			
Drainage Channel	3,881,500 c.y.	$ 0.81/c.y.	$ 3,144,000
Drainage Pump Stations	15	42,000/p.s.	630,000
Observation Wells			
1-1/4" Casing	15,200 lin.ft.	3.50/lin. ft.	53,200
Development	820 hrs.	25/hr.	20,500
Plunger Cylinders	152	140/cyl.	21,300
Total Seepage Control System			$ 3,869,000
SLUDGE MANAGEMENT	L.S.		$ 24,943,800
RENOVATED WATER CONVEYANCE SYSTEM			
Renovated Water Tunnel	10.606 miles	$1,928,000/mile	$20,448,000
Drop Shafts	L.S.		503,200
Total Renovated Water Conveyance System			$20,951,200

O & M COST SUMMARY FOR LAGOON TREATMENT SYSTEM
ST. CLAIR TREATMENT SITE

LABOR REQUIREMENTS

Equalization Lagoons	
7 Men @ $13,200	$ 92,400
+ 25% Overhead	20,600
Total	$113,000
Wastewater Conveyance System	
32 Men @ $13,200	$419,600
+ 25% Labor	104,900
Total	$524,500
Grit Removal & Screening	
16 Men @ $13,200	$210,000
+ 25% Overhead	52,500
Total	$262,500
Aerated Lagoons	
162 Men @ $13,200	$2,140,000
+ 25% Labor	535,000
Total	$2,675,000
Storage Lagoons	
27 Men @ $13,200	$364,800
+ 25% Overhead	91,200
Total	$456,000
Seepage Control	
6 Men @ $13,200	$ 80,000
+ 25% Overhead	20,000
Total	$100,000

O & M COST SUMMARY FOR LAGOON TREATMENT SYSTEM
ST. CLAIR TREATMENT SITE
(Cont.)

LABOR REQUIREMENTS (Cont.)			
Sludge Management			
125 Men @ $13,200		$1,648,000	
+ 25% Overhead		412,000	
Total		$2,060,000	
Renovated Water Conveyance System			
4 Men @ $13,200		$ 57,100	
+ 25% Overhead		14,300	
Total		$ 71,400	
Total Labor Cost (+ 25% Overhead)			$6,262,400
POWER COSTS @ $0.01/KILOWATT-HOUR			
Wastewater Pump Station	287,700HP-365 Days		$18,793,000
Aerated Lagoons	145,800HP-365 Days		9,526,000
Seepage Control	4,450HP-365 Days		2,900,000
Sludge Management			29,700
Total Power Costs			$31,248,700
CHEMICAL COSTS			
Chlorine @ $0.05/lb.			
Dosage $8^{mg}/L$			
26,610 Tons/yr.			$ 2,661,000

O & M COST SUMMARY FOR LAGOON TREATMENT SYSTEM
ST. CLAIR TREATMENT SITE
(Cont.)

MATERIALS & SUPPLIES		
Equalization Lagoons	@ 0.1% Capital Cost	$ 8,000
Wastewater Conveyance System		
Pump Station	@ 0.5% Capital Cost	177,100
Tunnel	@ 0.1% Capital Cost	85,200
Grit Removal & Screening	@ 0.1% Capital Cost	178,700
Aerated Lagoons	@ 0.5% Capital Cost	388,800
Storage Lagoons	@ 0.1% Capital Cost	168,600
Seepage Control	@ 0.5% Capital Cost	21,900
Sludge Management		1,050,000
Renovated Water System	@ 0.1% Capital Cost	35,700
Total Material & Supplies		$2,114,000

O & M COST SUMMARY FOR LAGOON TREATMENT SYSTEM
MONROE TREATMENT SITE

LABOR REQUIREMENTS

Equalization Lagoons	
7 Men @ $13,200	$ 92,000
+ 25% Overhead	21,000
Total	$113,000
Wastewater Conveyance	
24.5 Men @ $13,200	$323,200
+ 25% Overhead	80,800
Total	$404,000
Grit Removal & Screening	
10 Men @ $13,200	$132,000
+ 25% Overhead	37,000
Total	$169,000
Aerated Lagoons	
102 Men @ $13,200	$1,344,800
+ 25% Overhead	336,200
Total	$1,681,000
Storage Lagoons	
17.5 Men @ $13,200	$229,600
+ 25% Overhead	57,400
Total	$287,000
Seepage Control	
6 Men @ $13,200	$ 80,000
+ 25% Overhead	20,000
Total	$100,000

O & M COST SUMMARY FOR LAGOON TREATMENT SYSTEM
MONROE TREATMENT SITE
(Cont.)

LABOR REQUIREMENTS (cont.)			
Sludge Management			
37.5 Men @ $13,200		$496,000	
+ 25% Overhead		124,000	
Total		$620,000	
Renovated Water Conveyance			
2.5 Men @ $13,200		$ 34,000	
+ 25% Overhead		8,500	
Total		$ 42,500	
Total System Labor Costs			$3,416,500

POWER COSTS @ $0.01/KILOWATT-HOUR		
Wastewater Pump Station-	126,700HP-365 Days	$8,276,000
Aerated Lagoons -	91,800HP-365 Days	5,998,000
Drainage Pump Stations	4,770HP-365 Days	3,110,000
Sludge Pump Stations		8,400
Total Power Costs		$17,392,400
CHEMICAL COSTS		
Chlorine @ $0.05/lb.		
Dosage $8^{mg}/L$		
16,740 Tons/yr		$1,674,000

O & M COST SUMMARY FOR LAGOON TREATMENT SYSTEM
MONROE TREATMENT SITE
(Cont.)

MATERIALS & SUPPLIES		
Equalization Lagoons	@ 0.1% Capital Cost	$ 8,000
Wastewater Conveyance		
Pump Station	@ 0.5% Capital Cost	144,400
Tunnel	@ 0.1% Capital Cost	57,700
Grit Removal & Screening	@ 0.1% Capital Cost	106,700
Aerated Lagoons	@ 0.5% Capital Cost	253,300
Storage Lagoons	@ 0.1% Capital Cost	115,300
Seepage Control	@ 0.5% Capital Cost	24,200
Sludge Management		315,000
Renovated Water Conveyance		
Tunnel	@ 0.1% Capital Cost	21,000
Total Material & Supplies Cost		$1,045,600

ELECTRICAL CAPITAL COST FOR AERATED LAGOONS

A.	Motor Control Center for 400HP Unit	$ 7,000
B.	1200 Ft. of Cable for 400HP Units @ $2.00/Ft	2,400
C.	Transformer - 1 per Motor Control Center	2,000
D.	Transmission Poles - 2 @ $300	600
	Total Electrical Cost per 400HP Unit	$ 12,000
	Electrical Cost per HP = 12,000/400	$ 30/HP
E.	Misc. Lighting and Lines	$ 10/HP
	Use	$ 40/HP

ELECTRICAL COST SUMMARY

St. Clair Treatment Site:

972 Units @ 150HP

Electrical Cost = 972 (150) (40) $5,832,000

Monroe Treatment Site:

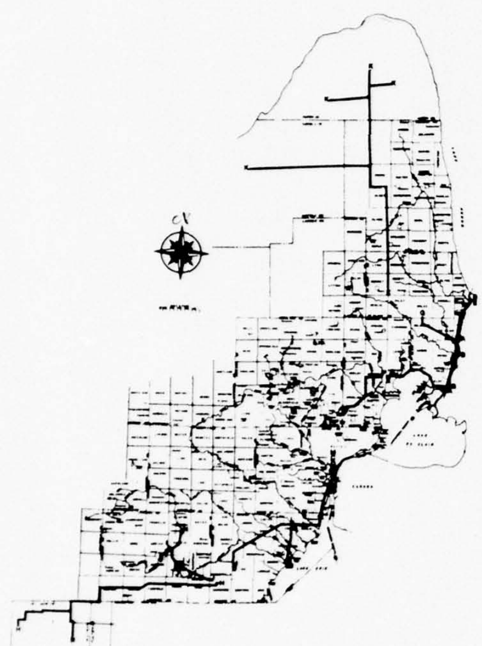
612 Units @ 150HP

Electrical Cost = 612 (150) (40) $3,672,000

EXHIBITS

DETROIT DISTRICT
U.S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM
IDACW 35-72-C-0034



PROJECT LOCATION MAP

LIST OF EXHIBITS

EXHIBIT	CONVEYANCE SYSTEM	DESCRIPTION
1	St. Clair Conveyance System	Tunnel in rock from equalizing lagoon in Chesterfield TWP to St. Clair Treatment lagoon site
2	Monroe Conveyance System	Tunnel in rock from equalizing lagoon in Berlin TWP to Monroe Treatment lagoon site
3	St. Clair Renovated Water System	Renovated water tunnel from St. Clair site to St. Clair River
4	Monroe Renovated Water System	Renovated water tunnel from Monroe treatment site to Lake Erie
5	A	Interceptors from St. Clair TWP and Algonac to treatment plant at E. China TWP
6	B	Interceptor from Port Huron to treatment plant at E. China TWP
7	C	Tunnel in rock from Detroit to treatment plant at the mouth of the Huron site.
8	D	Tunnel in rock (or interceptor in glacial drift) from Monroe to plant at the mouth of the Huron River
9	E	Interceptor from Port Huron through E. China TWP, Algonac and New Baltimore to equalizing lagoon in Chesterfield TWP
10	F	Tunnels in rock (and interceptors from Red Run Area to St. Clair lagoon treatment site
11	G	Interceptor along St. Clair Shoreline with transmission to St. Clair irrigation area
12	H	Force main from Monroe Lagoon site to Fulton-Williams irrigation site
13	I	Interceptor from juncture of River Raisin to Lenawee irrigation site
14	J	Monroe lagoon site to Lenawee irrigation site
15	K	Force main from St. Clair lagoon treatment site to Huron-Tuscola irrigation site
16	L	Tunnel in rock (or interceptor in glacial drift) from Wyandotte to treatment plant at the mouth of the Huron River
17	M	Tunnel in rock (or interceptor in glacial drift) from Detroit to Monroe lagoon treatment site
18	N	Interceptors from Tecumseh and Adrian to proposed treatment plant at juncture of River Raisin and South Branch of River Raisin

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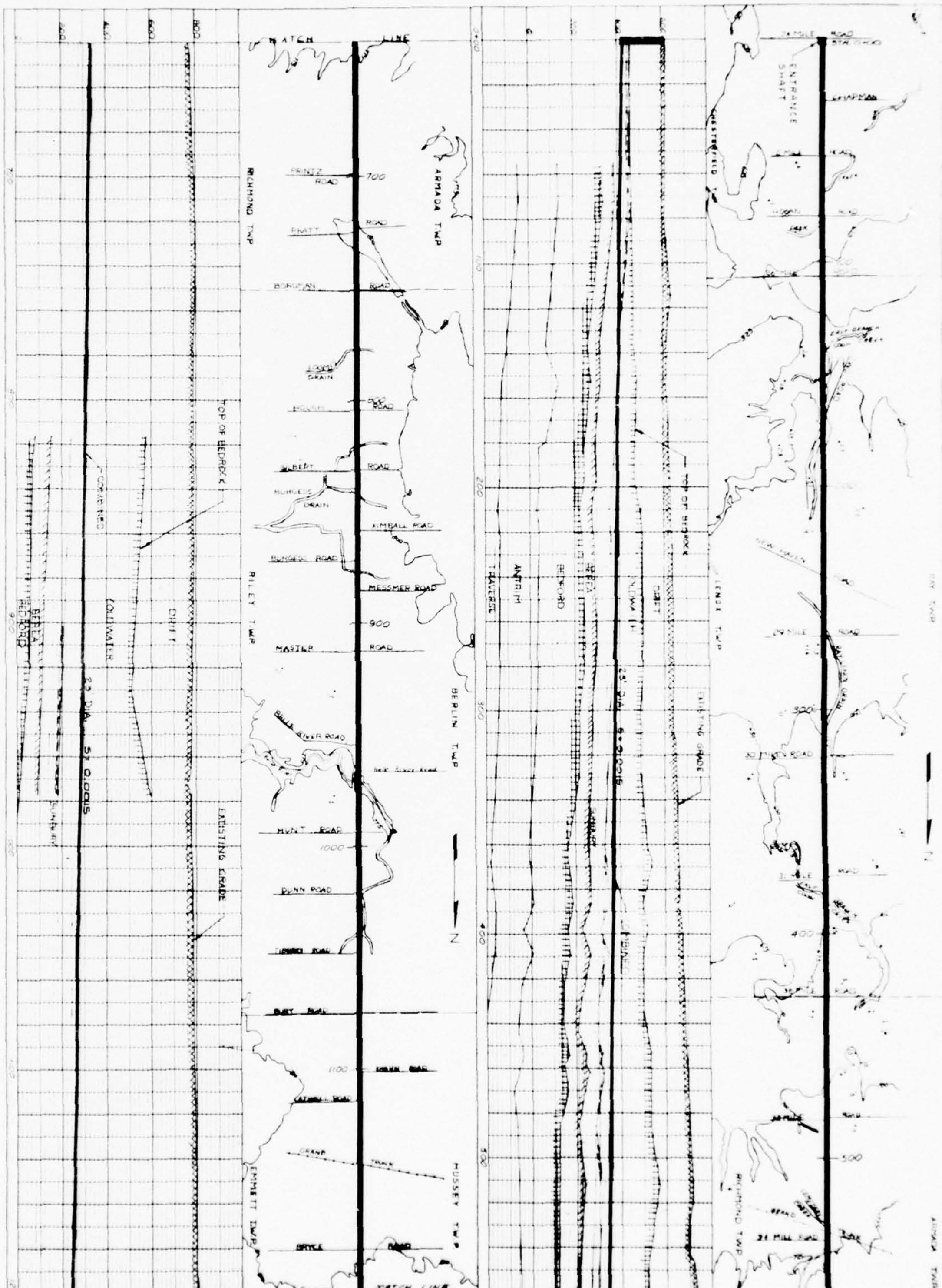
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

COVER SHEET

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev No
Project 1013.002	NOVEMBER 1972

Design by | Date | Checked by | Date | Drawn by | Date | Checked by | Date | Revised by | Date | Checked by | Date



DETROIT DISTRICT
U.S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT I
ST CLAIR CONVEYANCE SYSTEM

BAUER ENGINEERING, INC
CHICAGO, ILLINOIS

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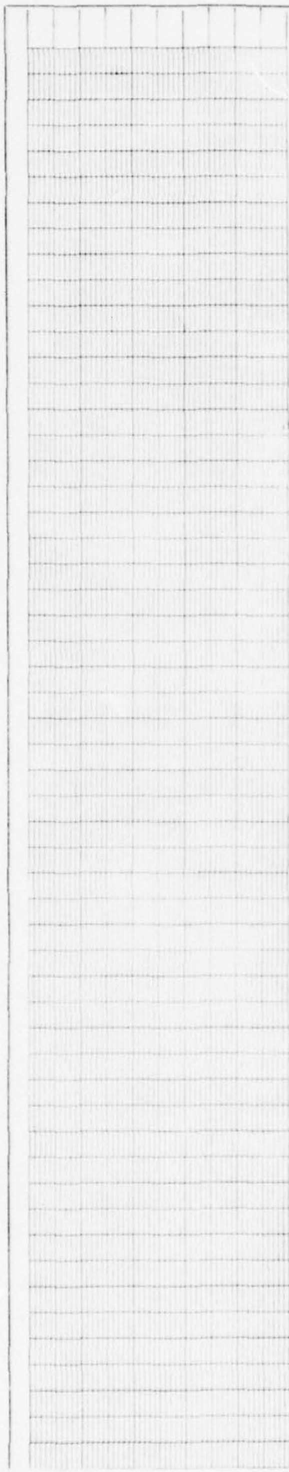

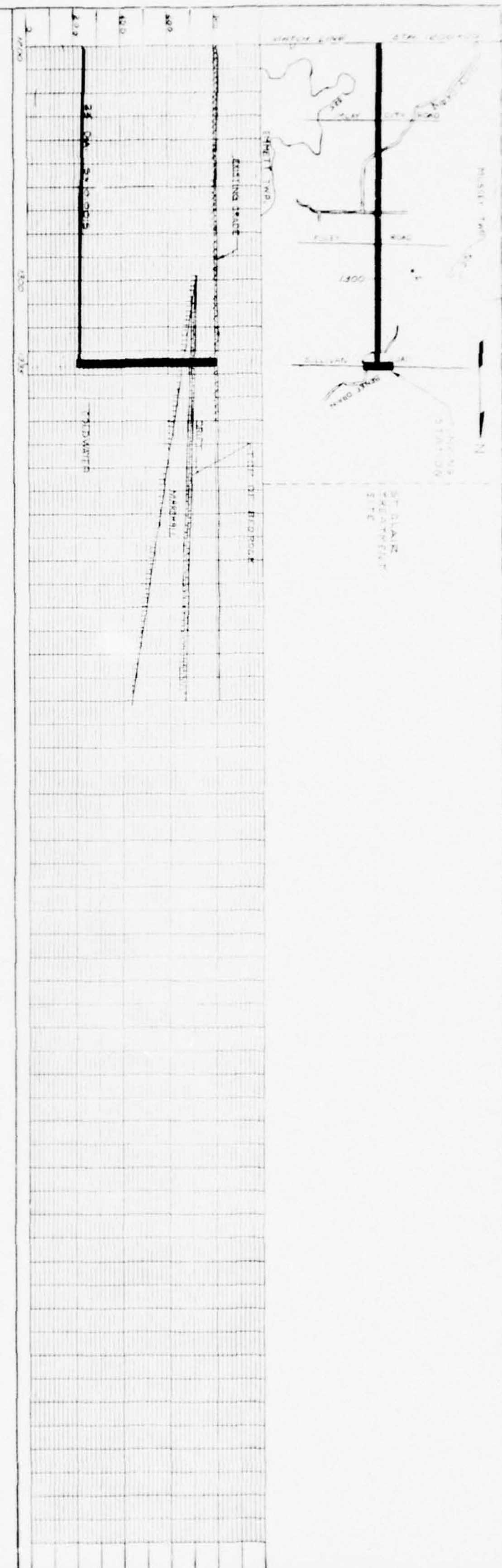

DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT I

ST. CLAIR CONVEYANCE SYSTEM

TUNNEL IN ROCK FROM EQUALIZING LAGOON IN CHESTERFIELD TWP TO ST. CLAIR TREATMENT LAGOON SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No.
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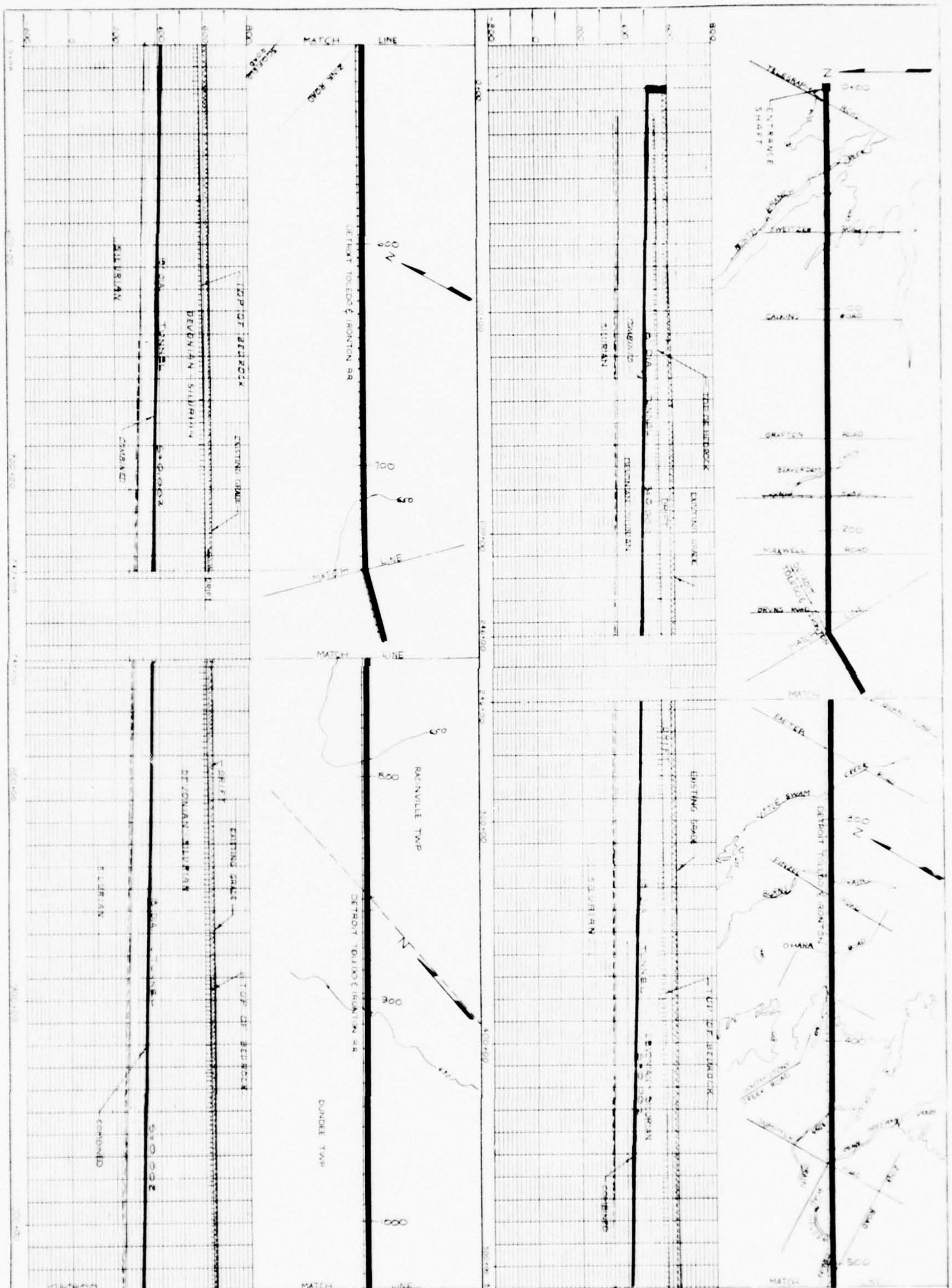
SCALE IN FEET

HORIZONTAL 2000 0 2000

VERTICAL 200 0 200



DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 2
MONROE CONVEYANCE SYSTEM

TUNNEL IN ROCK FROM EQUALIZING LAGOON IN
BERLIN TWP TO MONROE TREATMENT LAGOON SITE

SCALE IN FEET
HORIZONTAL 0 2000
VERTICAL 0 200

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No
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SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 2
MONROE CONVEYANCE SYSTEM

TUNNEL IN ROCK FROM EQUALIZING LAGOON IN BERLIN TWP TO MONROE TREATMENT LAGOON SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No
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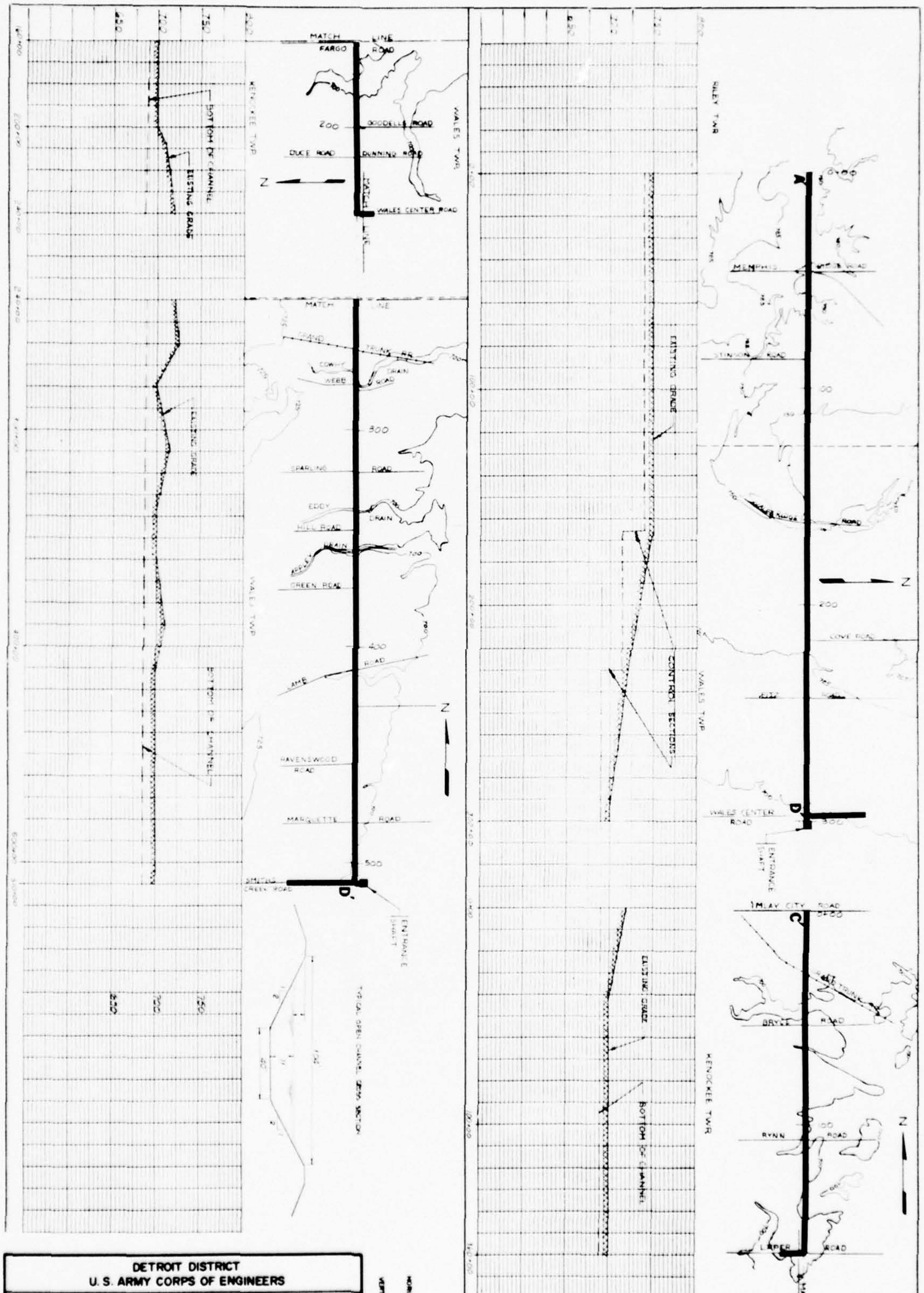

DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 3
ST CLAIR RENOVATED WATER SYSTEM

BAUER ENGINEERING, INC.
CHICAGO, ILLINOIS

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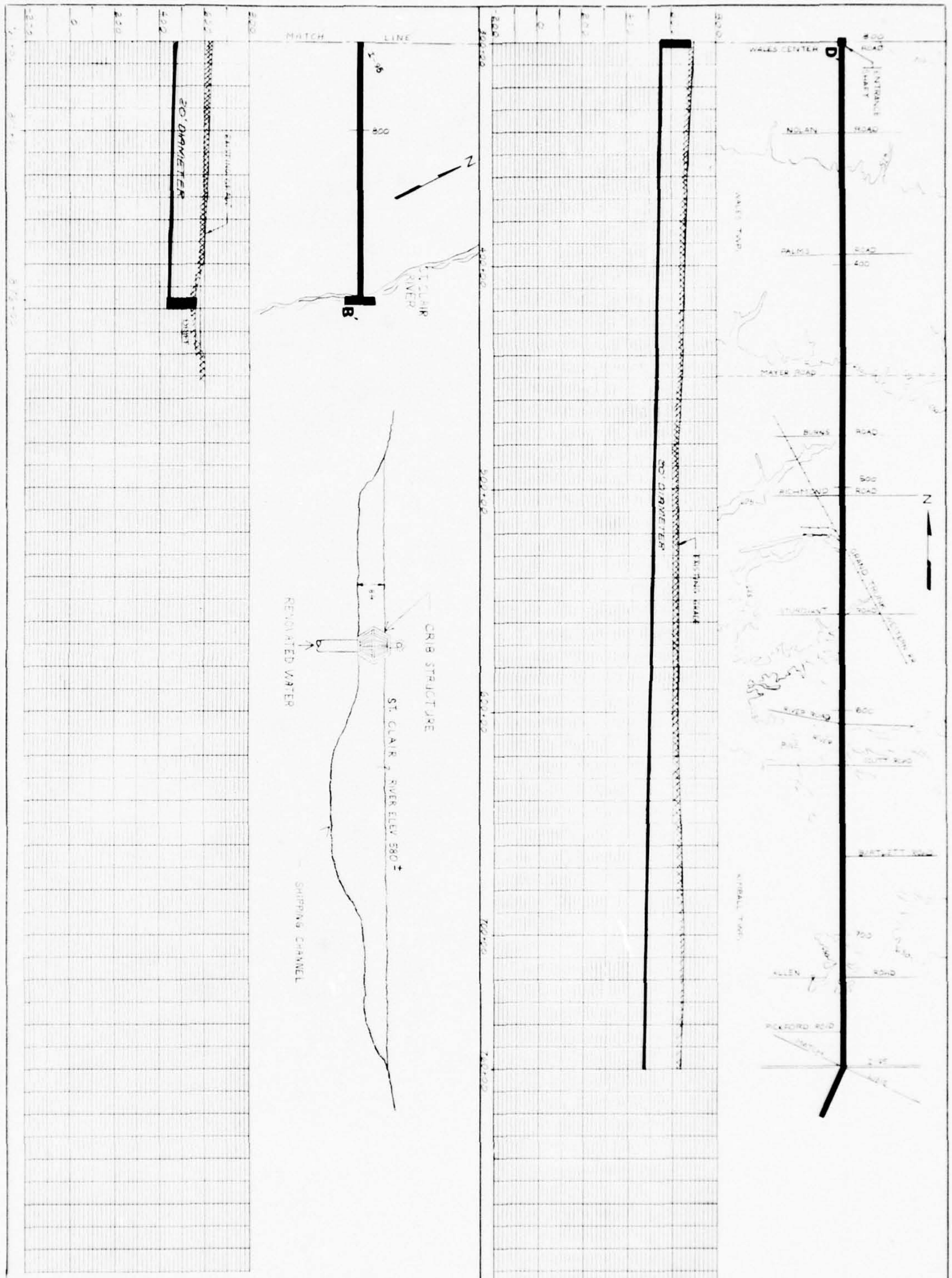

DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 3
ST CLAIR RENOVATED WATER SYSTEM

BAUER ENGINEERING, INC.
CHICAGO, ILLINOIS

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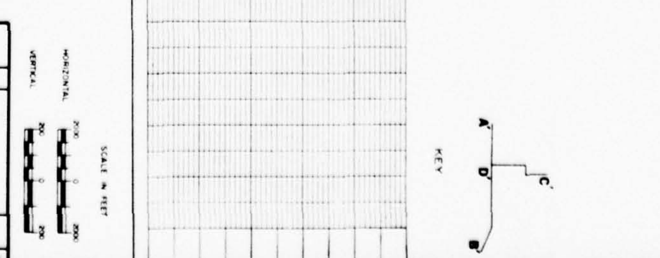

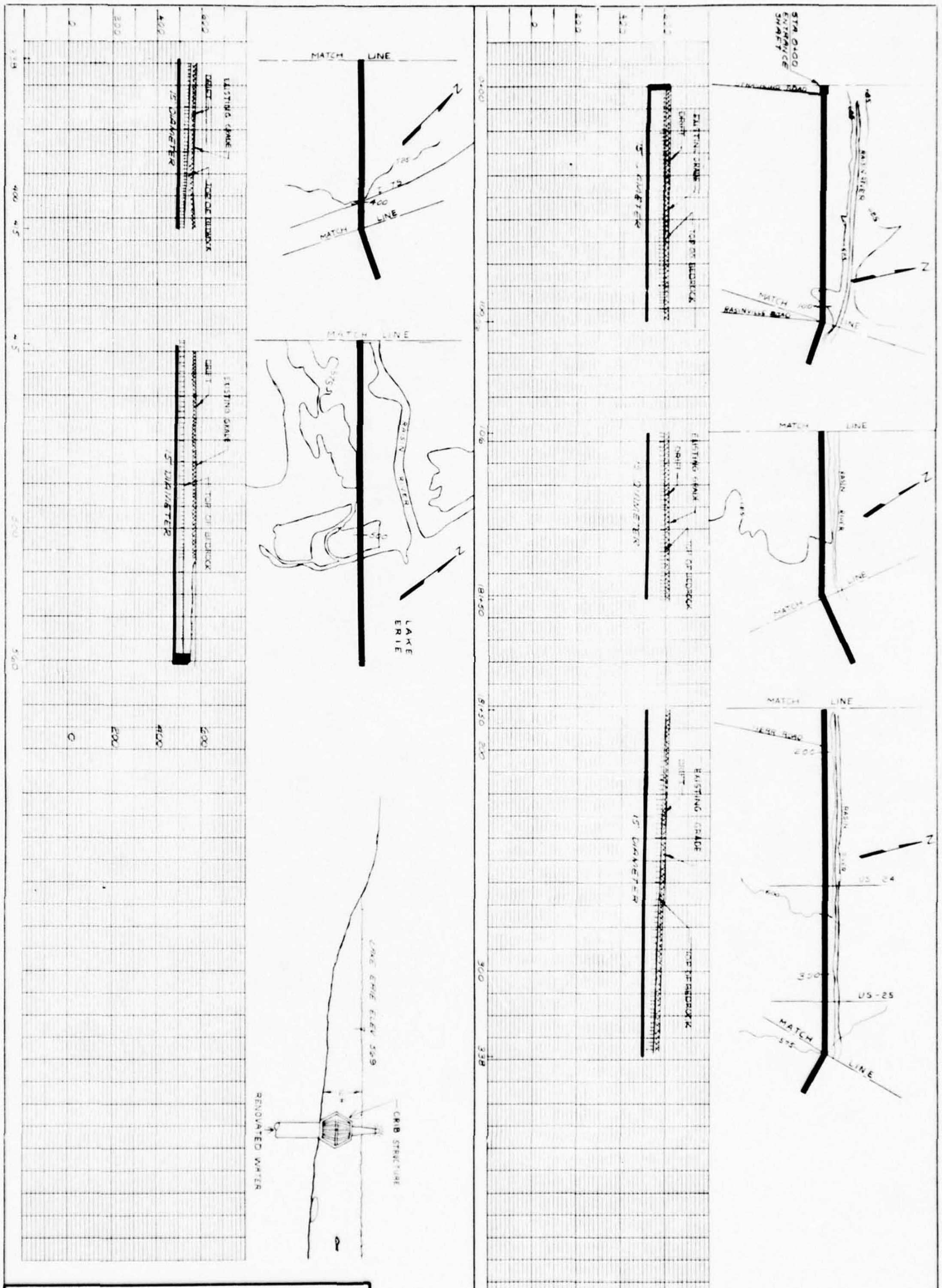

DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 4
MONROE RENOVATED WATER SYSTEM

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No
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SCALE IN FEET
HORIZONTAL 2000 0 2000
VERTICAL 200 0 200

DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM
EXHIBIT 5
CONVEYANCE SYSTEM A
BAUER ENGINEERING, INC.
CHICAGO, ILLINOIS
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SHEET 1 OF 1
SCALE IN FEET
HORIZONTAL
VERTICAL
ONTARIO
ST. CLAIR RIVER
MICHIGAN
ROBERTS ROAD
SPRINGBORN ROAD
RECOR ROAD
REMER ROAD
PUTTYGUT ROAD
EAST CHINA TWP

DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 6
CONVEYANCE SYSTEM B

INTERCEPTOR FROM PORT HURON TO
TREATMENT PLANT AT E. CHINA TWP

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No
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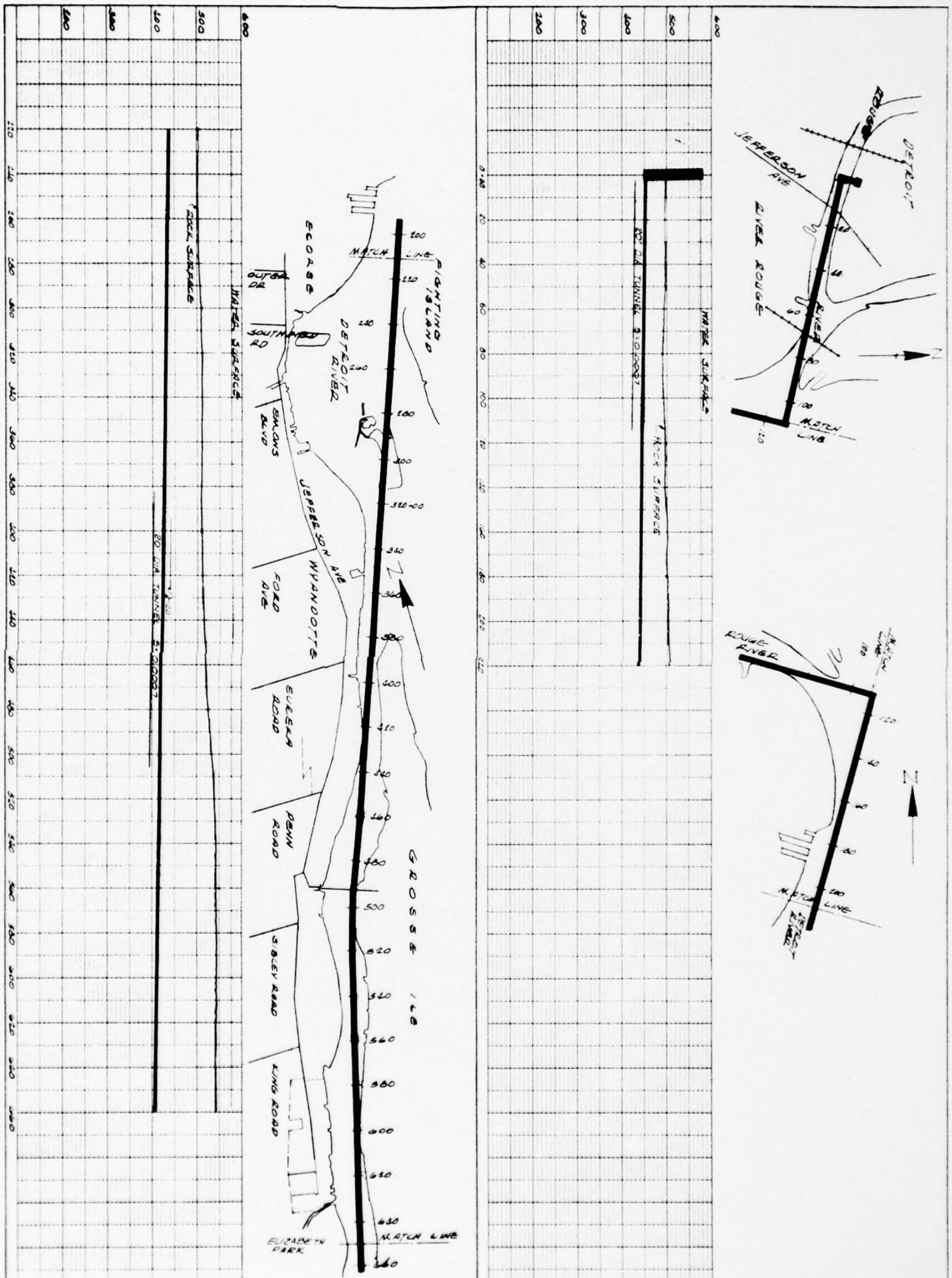


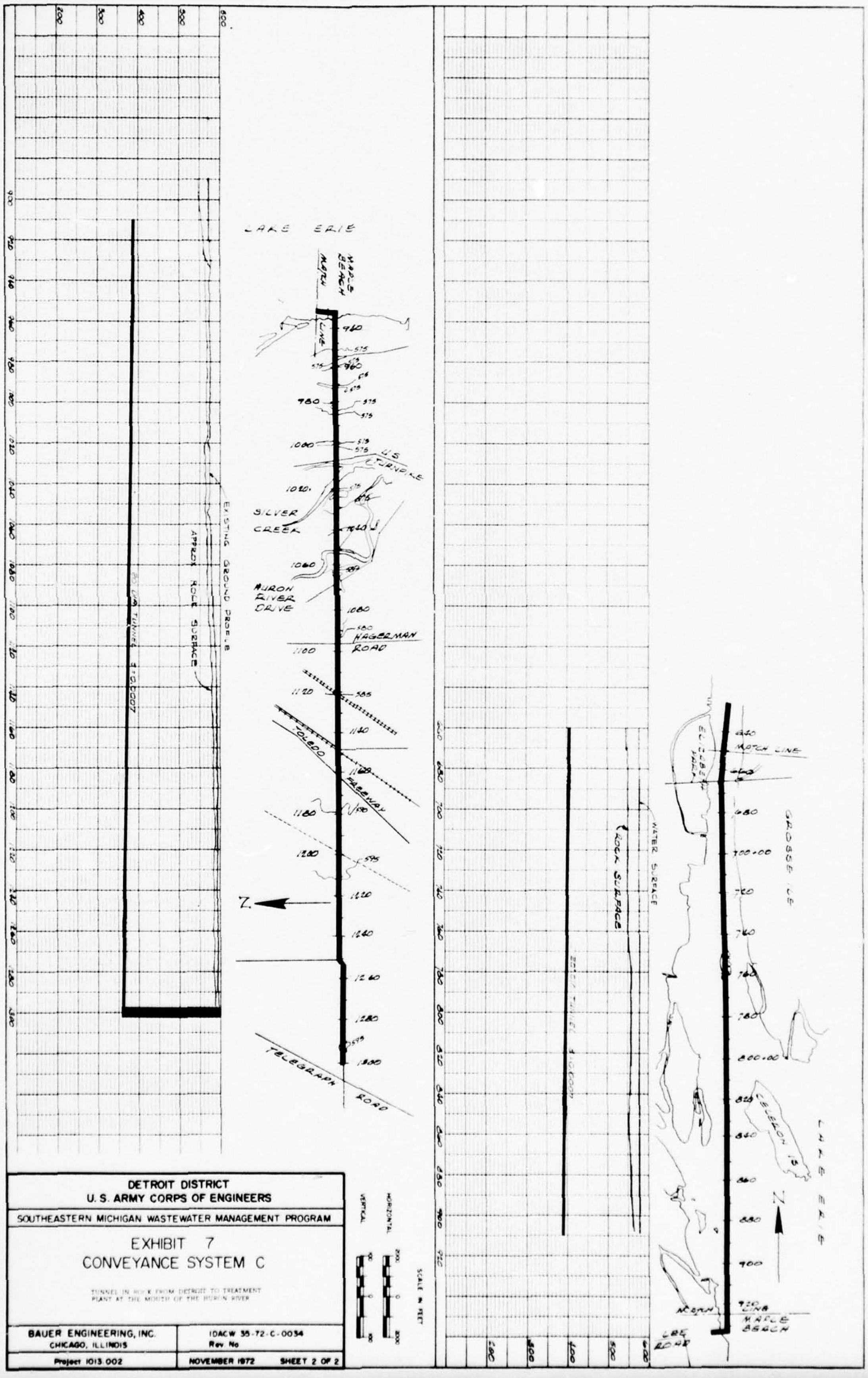
DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 7
CONVEYANCE SYSTEM C

TUNNEL IN ROCK FROM DETROIT TO TREATMENT PLANT AT THE MOUTH OF THE HURON RIVER

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No
Project 1013.002	NOVEMBER 1972 SHEET 1 OF 2



DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 7
CONVEYANCE SYSTEM C

TUNNEL IN ROCK FROM DETROIT TO TREATMENT PLANT AT THE MOUTH OF THE HURON RIVER

BAUER ENGINEERING, INC.
CHICAGO, ILLINOIS

IDACW 35-72-C-0034
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Project 1013.002

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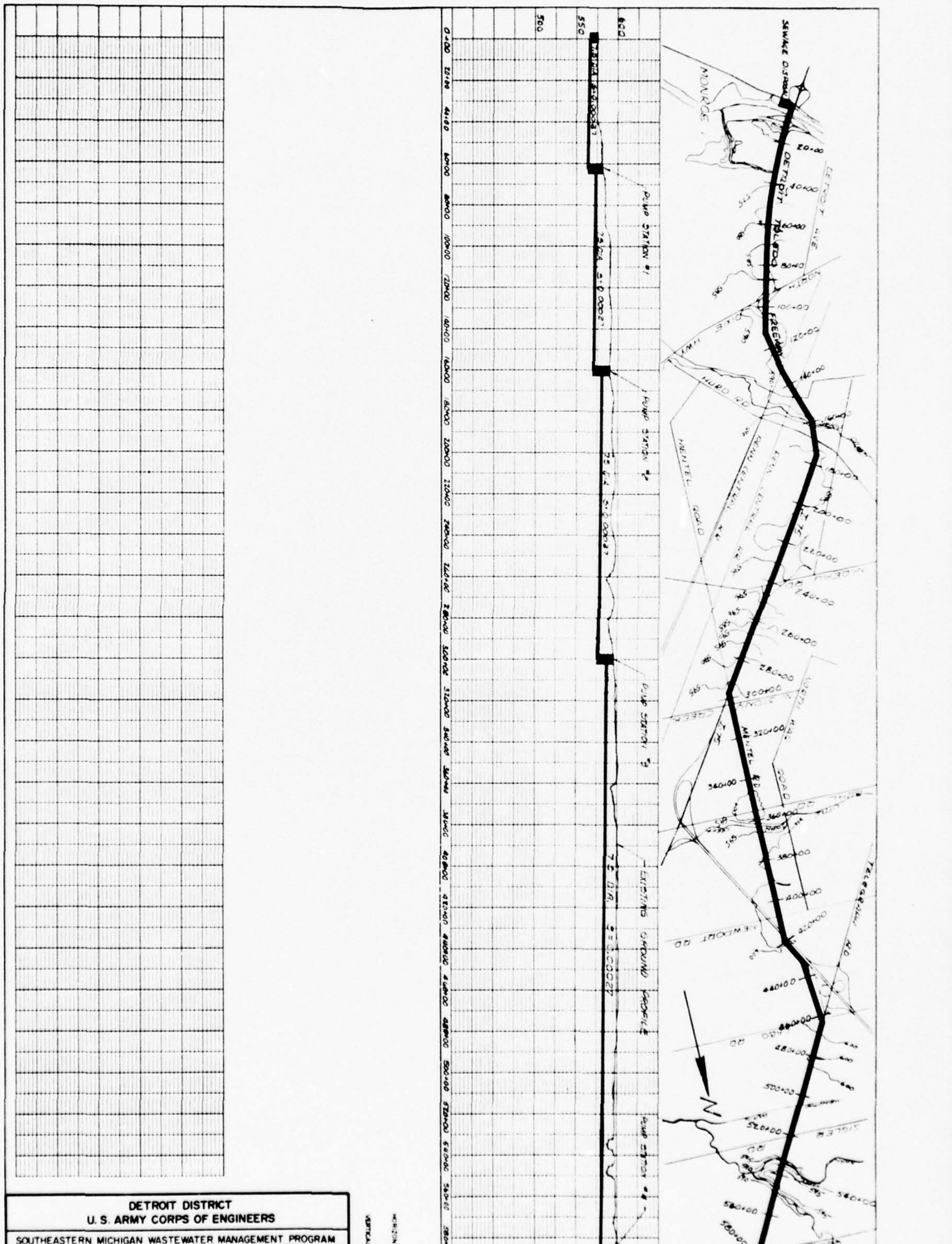

DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 8
CONVEYANCE SYSTEM D

TUNNEL IN ROCK (OR INTERCEPTOR IN GLACIAL DRIFT) FROM MONROE TO PLANT AT THE MOUTH OF THE HURON RIVER

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev No
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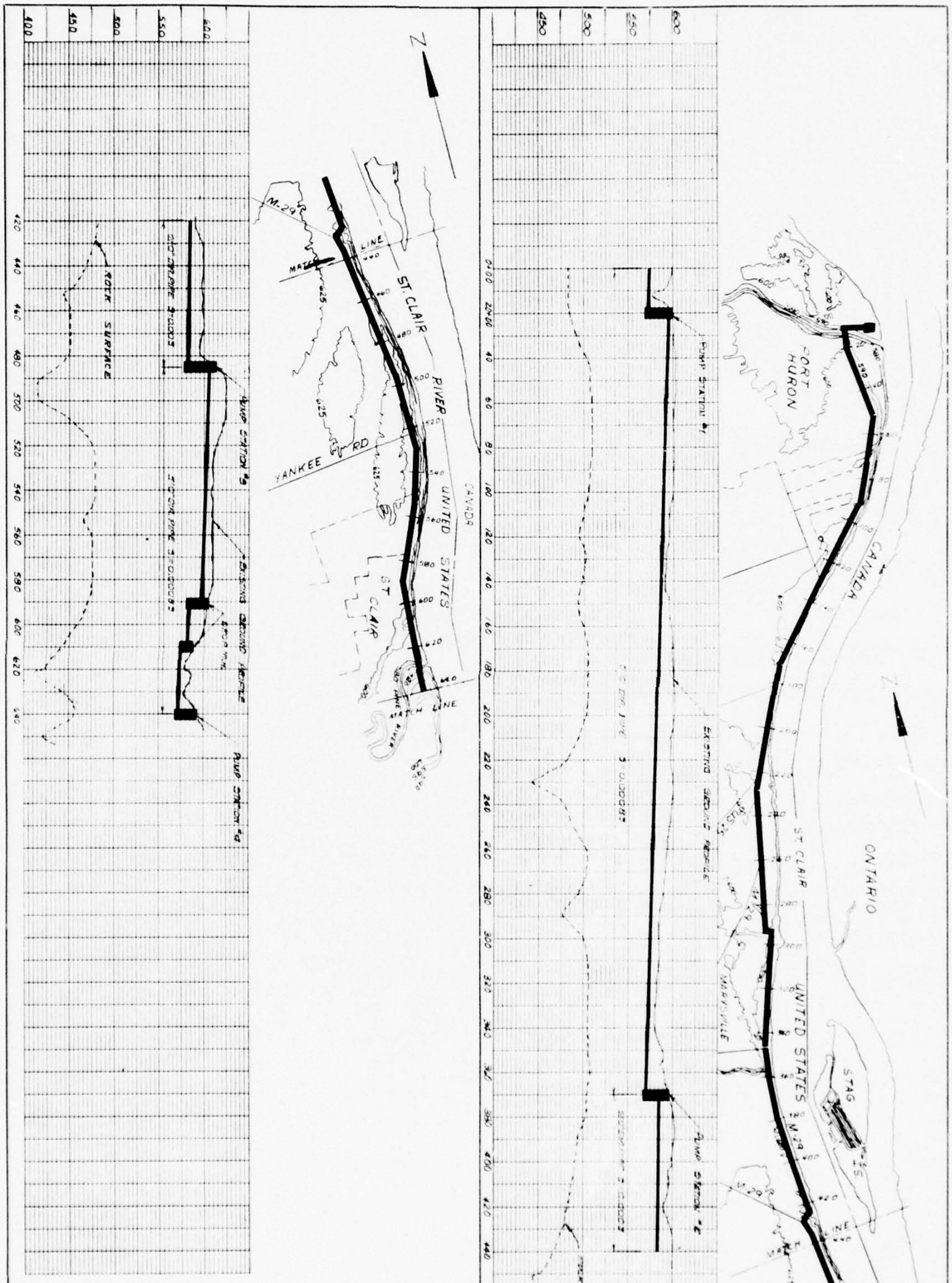


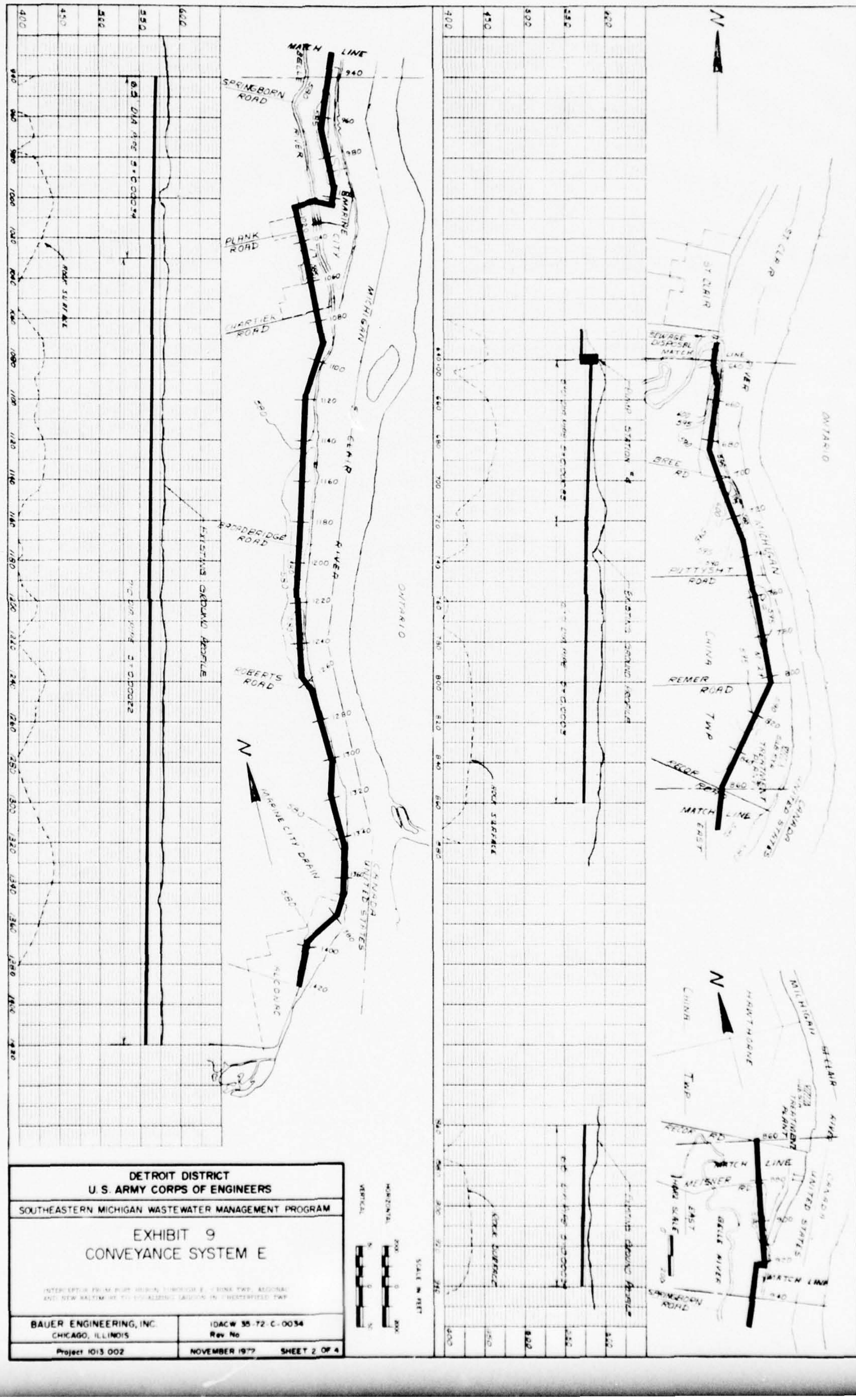
DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

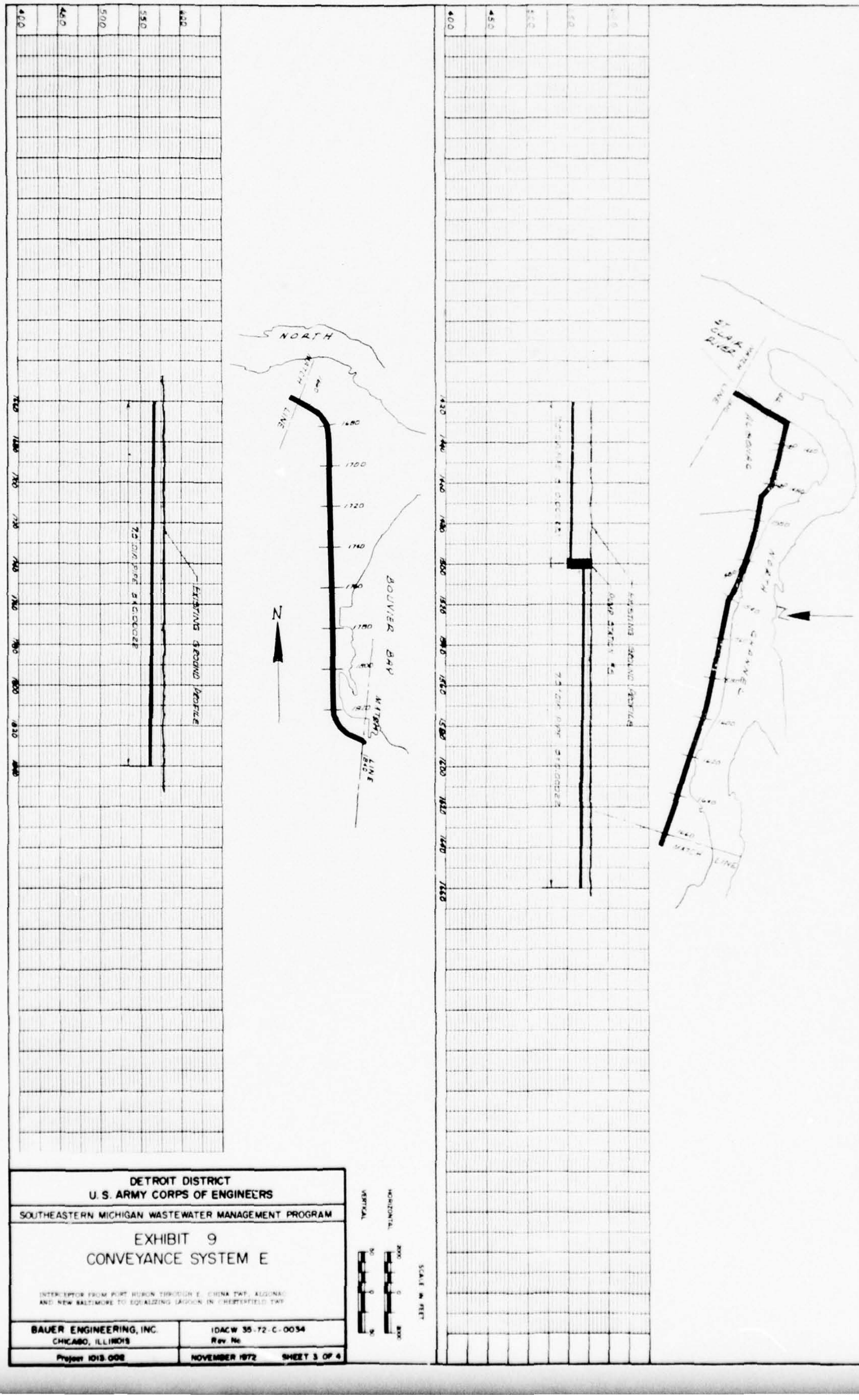
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 9
CONVEYANCE SYSTEM E

INTERCEPTOR FROM PORT HURON THROUGH E. CHINA TWP, ALGONAC AND NEW BALTIMORE TO EQUALIZING LAGOON IN CHESTERFIELD TWP

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev No
Project 1013.002	NOVEMBER 1972 SHEET 1 OF 4


DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM
EXHIBIT 9
CONVEYANCE SYSTEM E
BAUER ENGINEERING, INC.
CHICAGO, ILLINOIS
Project 1013.002
IDACW 35-72-C-0034
Rev. No
NOVEMBER 1977
SHEET 2 OF 4
SCALE IN FEET
HORIZONTAL
VERTICAL
MATCH LINE
SPRINGBORN ROAD
PLANK ROAD
CHARTIER ROAD
BROADBRIDGE ROAD
ROBERTS ROAD
MARINE CITY DRAIN
MARINE CITY
ST. CLAIR RIVER
MICHIGAN
ONTARIO
CANADA
UNITED STATES
EXISTING GROUND PROFILE
ROCK SURFACE
PUMP STATION #4
ST. CLAIR
SEWAGE DISPOSAL
BREE RD
PUTTYGUT ROAD
REMER ROAD
CHINA TWP
RECOR RD
MEISNER RD
BELLE RIVER



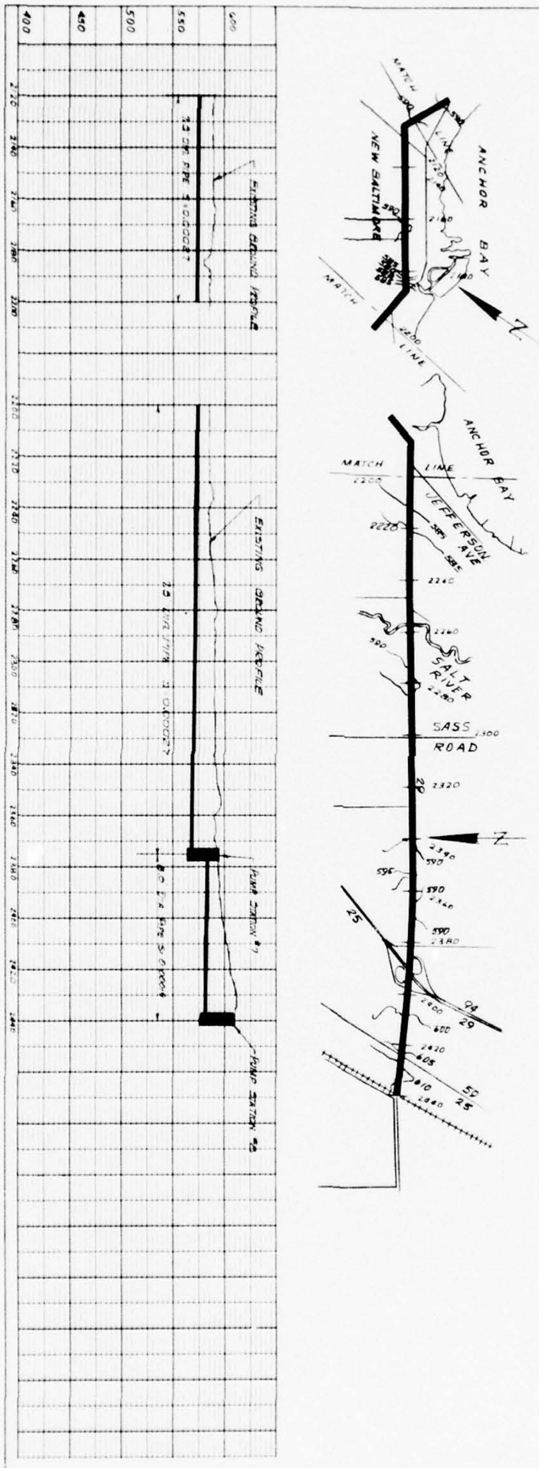
DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

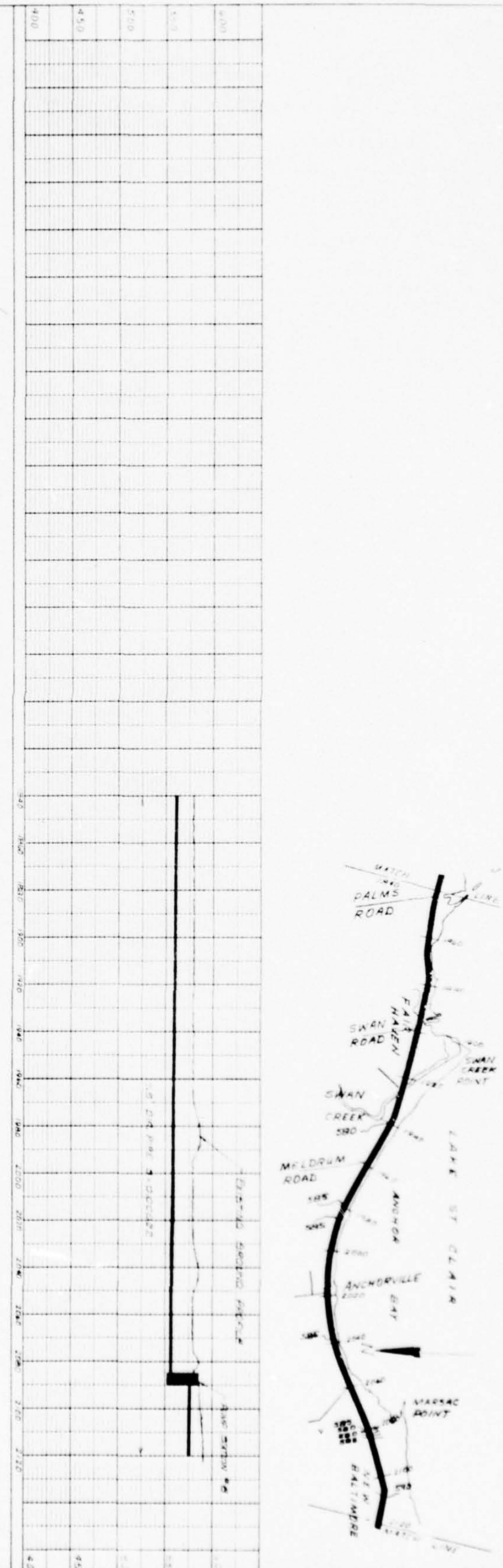
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 9
CONVEYANCE SYSTEM E

INTERCEPTOR FROM PORT HURON THROUGH E. CHINA TWP., ALGONAC AND NEW BALTIMORE TO EQUALIZING LAGOON IN CHESTERFIELD TWP.

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No.
Project 1013-008	NOVEMBER 1972 SHEET 3 OF 4





DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

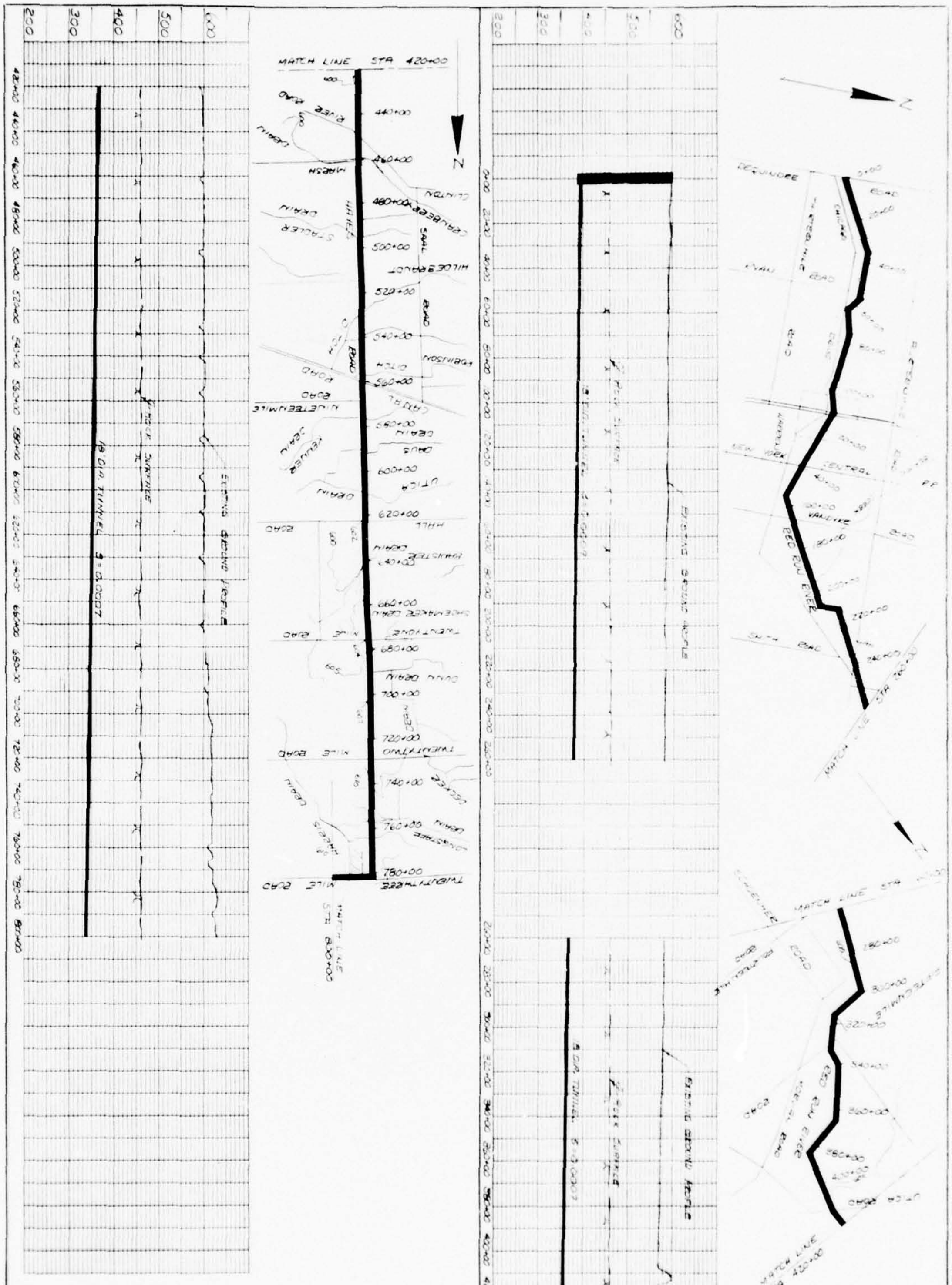
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 9
CONVEYANCE SYSTEM E

INTERCEPTOR FROM PORT HURON THROUGH E. CHINA TWP., ALGONAC AND NEW BALTIMORE TO EQUALIZING LAGOON IN CHESTERFIELD TWP.

SCALE IN FEET
HORIZONTAL
VERTICAL

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No
Project 1013.002	NOVEMBER 1972 SHEET 4 OF 4



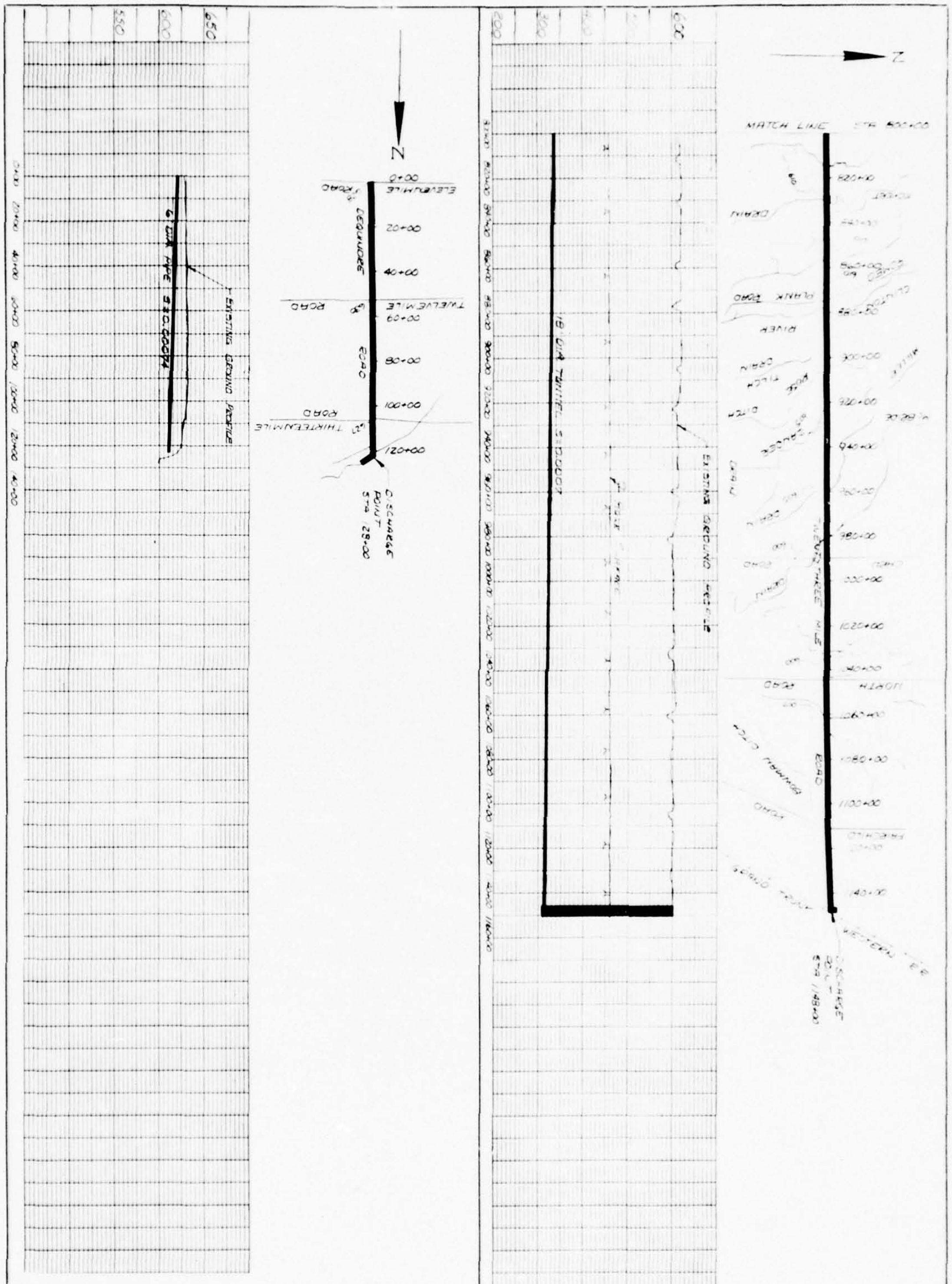
DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 10
CONVEYANCE SYSTEM F

TUNNELS IN ROCK AND INTERCEPTORS FROM RED RUN AREA TO ST. CLAIR GROUND TREATMENT SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No.
Project 1013.002	NOVEMBER 1972 SHEET 1 OF 2



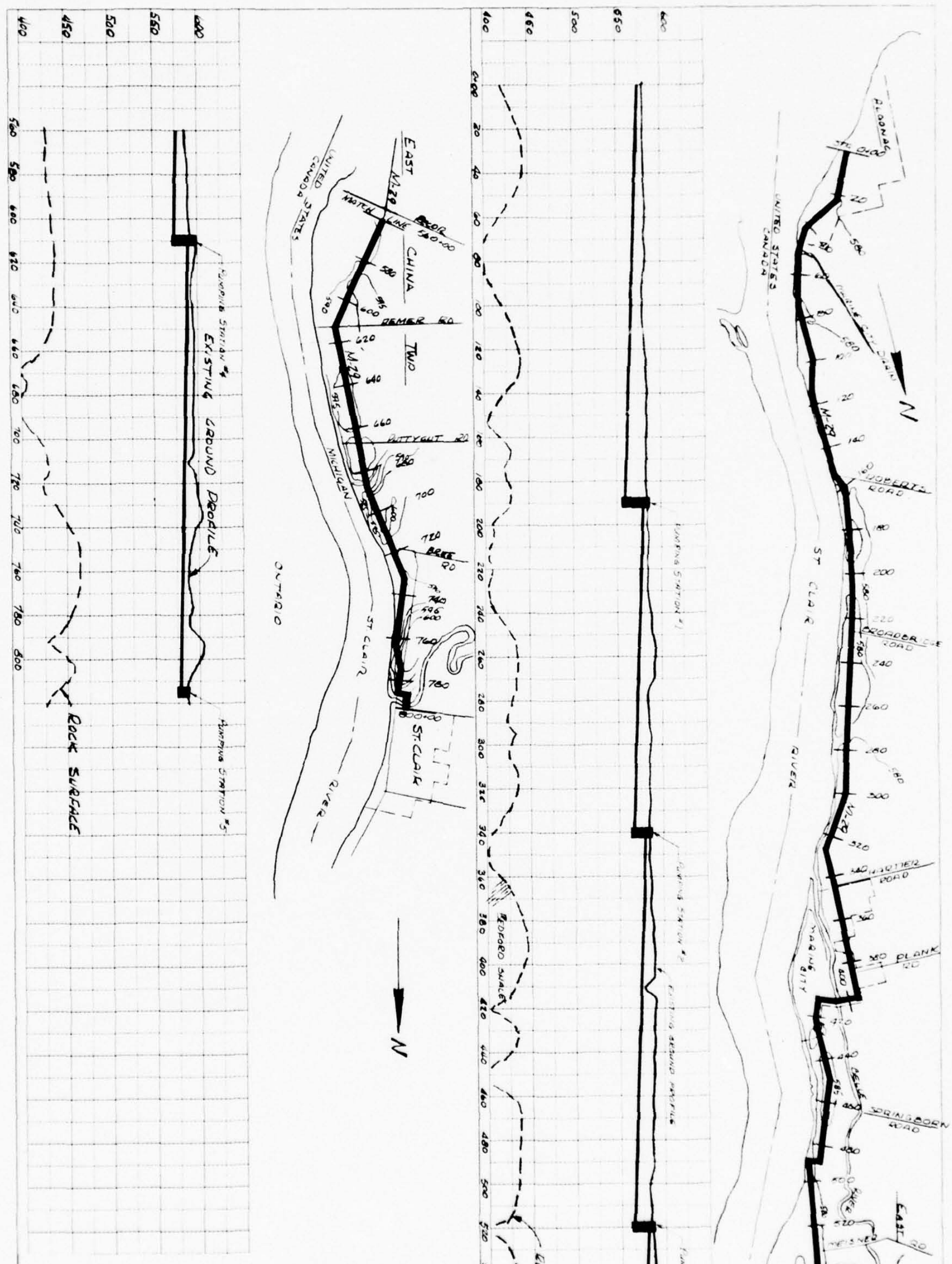
DETROIT DISTRICT
U.S. ARMY CORPS OF ENGINEERS

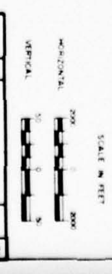
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 10
CONVEYANCE SYSTEM F

TUNNELS IN ROCK AND INTERCEPTORS FROM RED RUN AREA TO ST. CLAIR LAGOON TREATMENT SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev No
Project 1013.002	NOVEMBER 1972 SHEET 2 OF 2





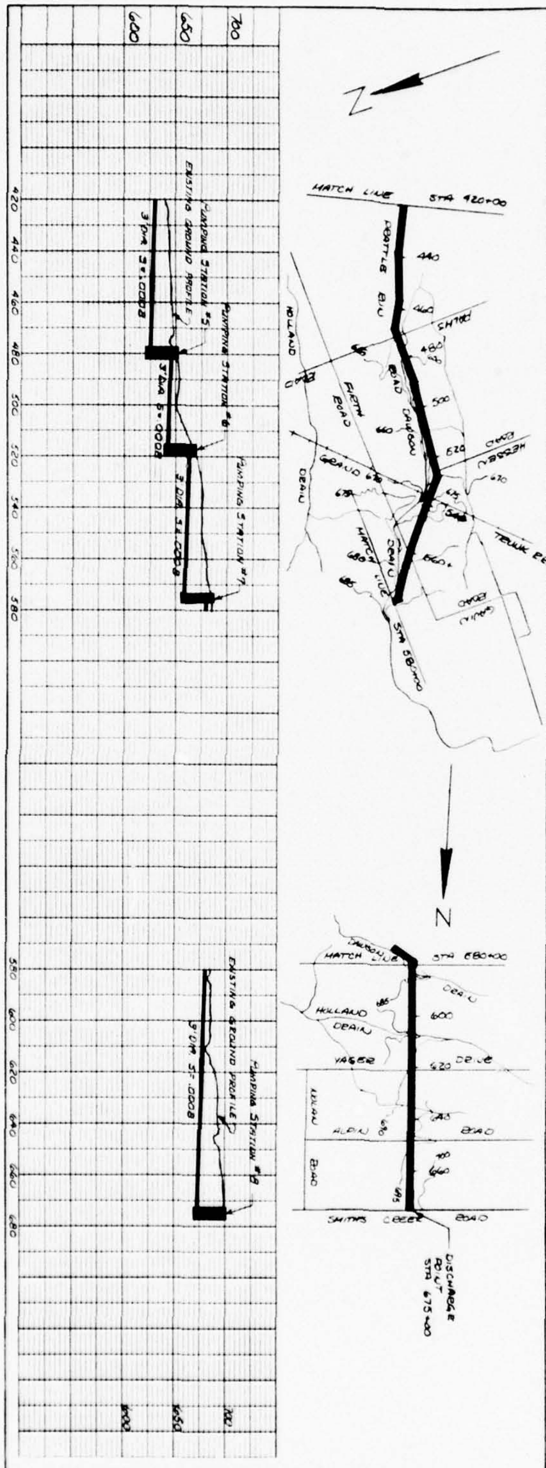
DETROIT DISTRICT
U.S. ARMY CORPS OF ENGINEERS

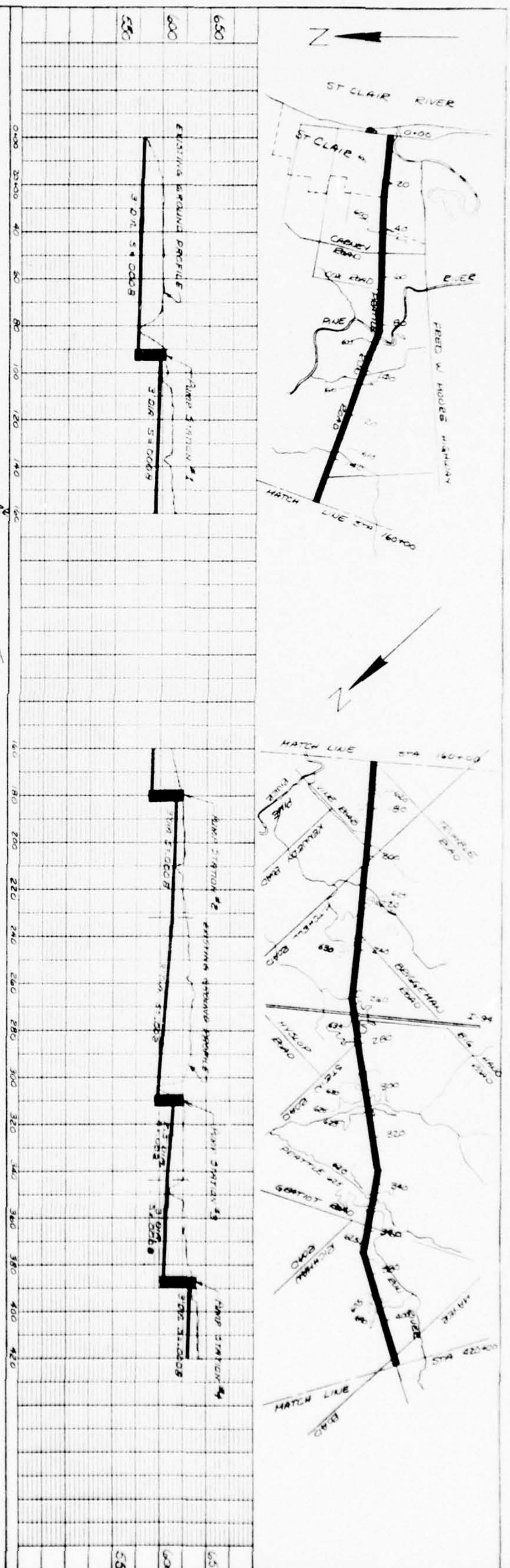
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 11
CONVEYANCE SYSTEM G

INTERCEPTOR ALONG ST. CLAIR SHORELINE WITH
TRANSMISSION TO ST. CLAIR IRRIGATION AREA

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No
Project 1013.002	NOVEMBER 1972 SHEET 1 OF 2





DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 11
CONVEYANCE SYSTEM G

INTERCEPTOR ALONG ST. CLAIR SHORELINE WITH TRANSMISSION TO ST. CLAIR IRRIGATION AREA

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No.
Project 1013.002	NOVEMBER 1972 SHEET 2 OF 2

SCALE IN FEET
HORIZONTAL 2000 0 2000
VERTICAL 50 0 50

DETROIT DISTRICT
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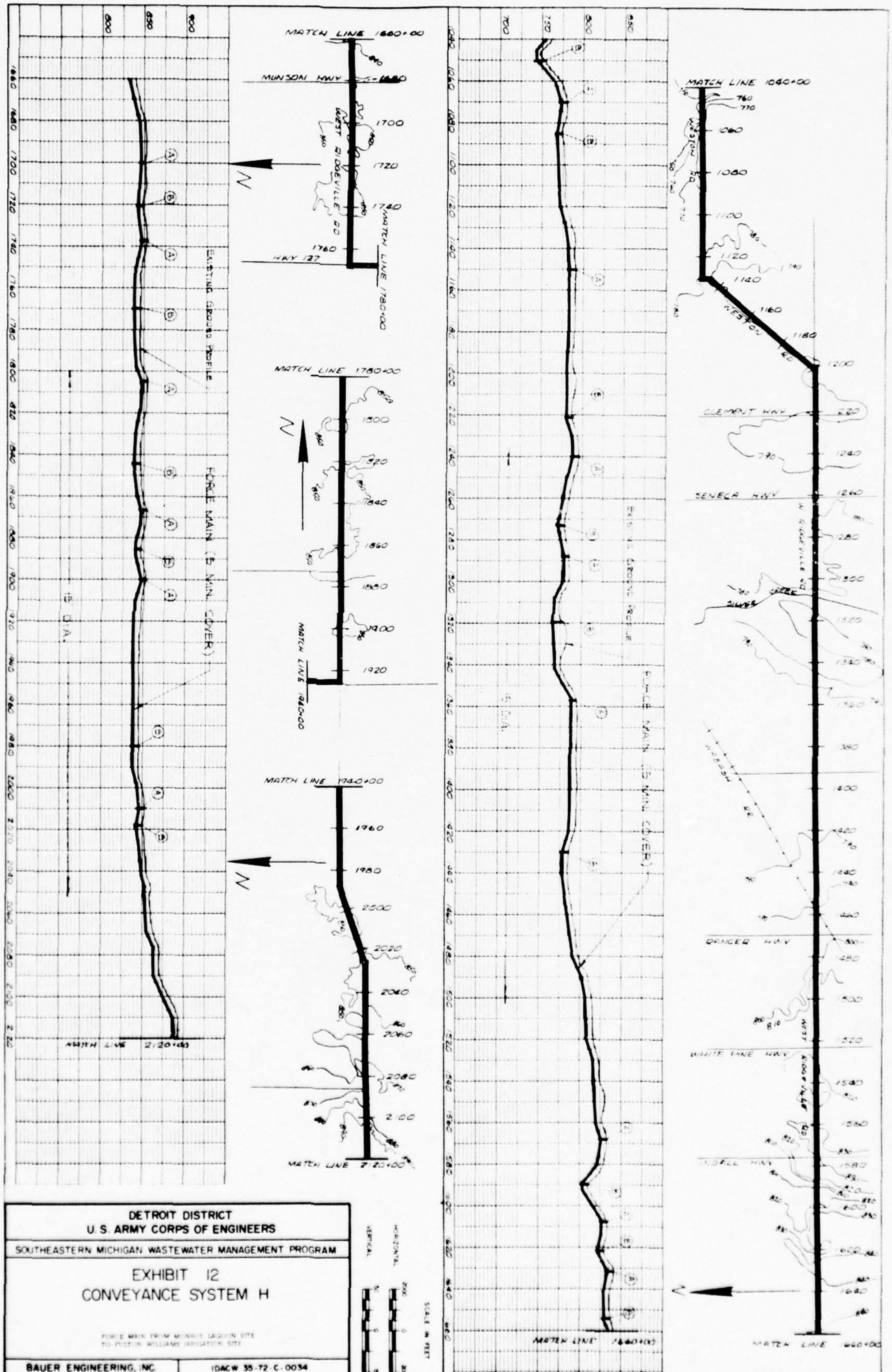
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 12
CONVEYANCE SYSTEM H

FORCE MAIN FROM MONROE LAGOON SITE
TO FULTON WILLIAMS IRRIGATION SITE

SCALE IN FEET
HORIZONTAL 2000 0 2000
VERTICAL 50 0 50

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No
Project 1013.002	NOVEMBER 1972 SHEET 1 OF 4

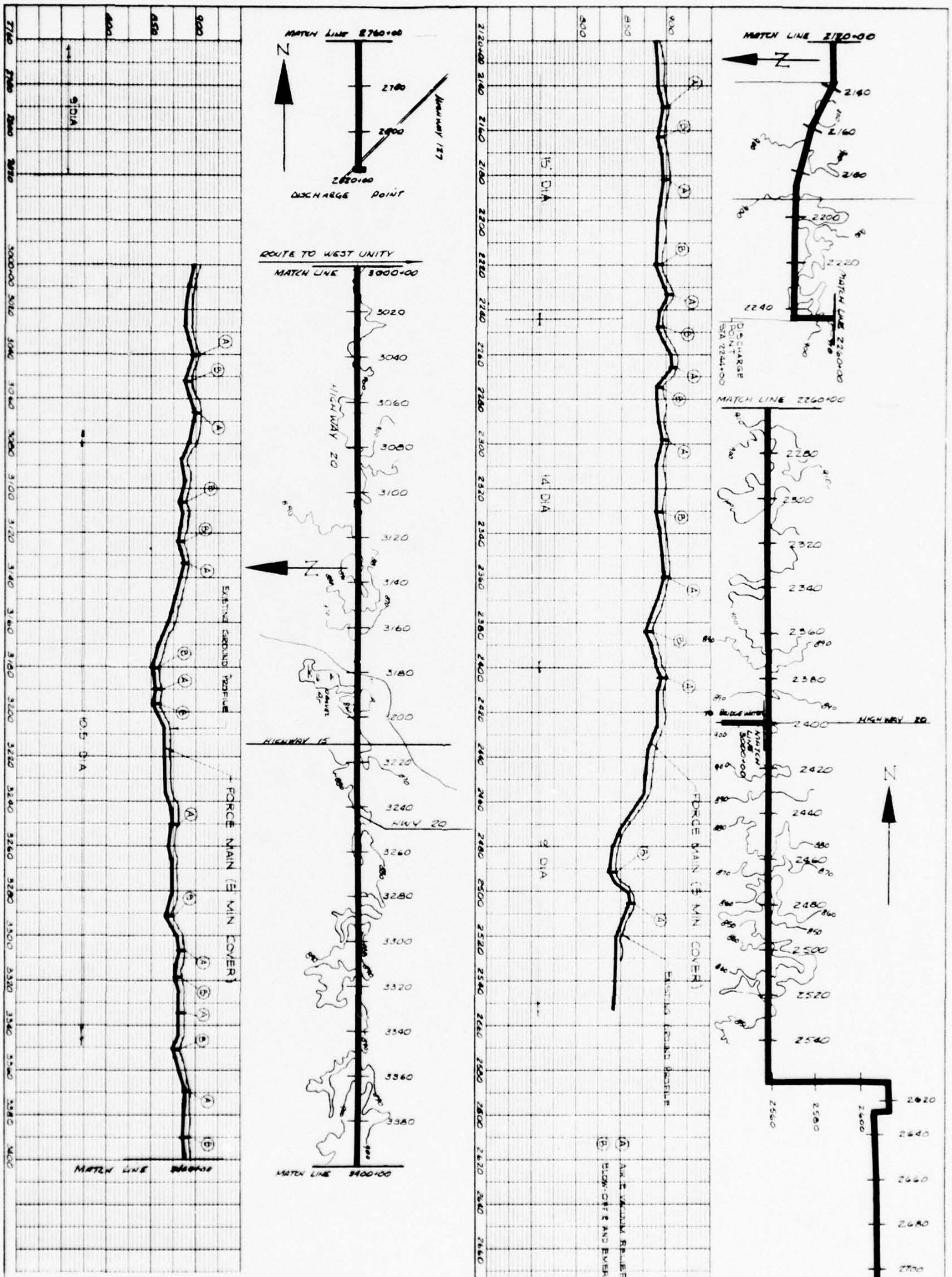


DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 12
CONVEYANCE SYSTEM H

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev No
Project 1013.002	NOVEMBER 1972 SHEET 2 OF 4



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U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 12
CONVEYANCE SYSTEM H

FORCE MAIN FROM MONROE LAGOON SITE TO FULTON-WILLIAMS IRRIGATION SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No
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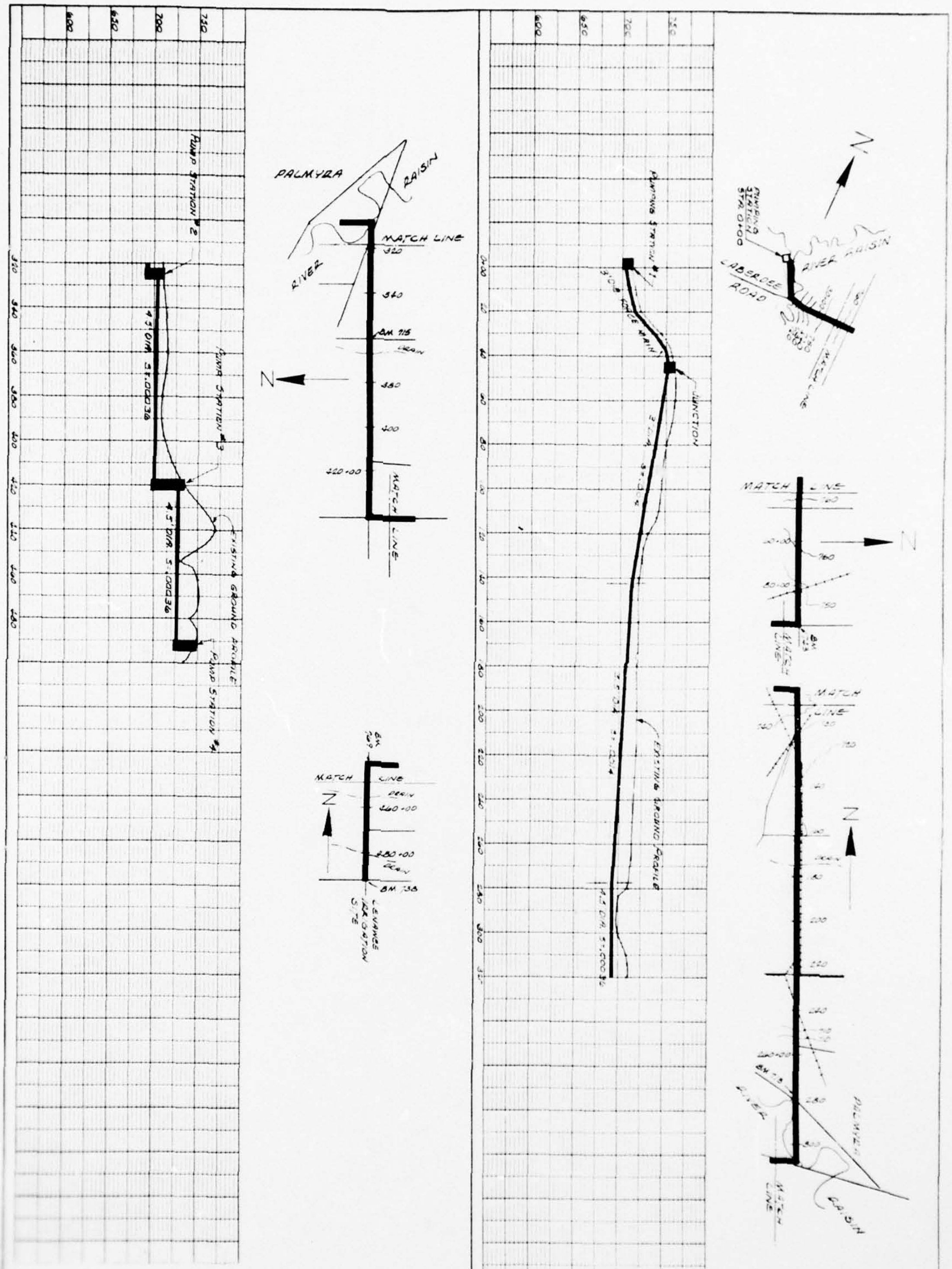
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 12
CONVEYANCE SYSTEM H

FORCE MAIN FROM MONROE LAGOON SITE TO FULTON-WILLIAMS IRRIGATION SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No.
Project 1013 002	NOVEMBER 1972 SHEET 4 OF 4



DETROIT DISTRICT
U.S. ARMY CORPS OF ENGINEERS

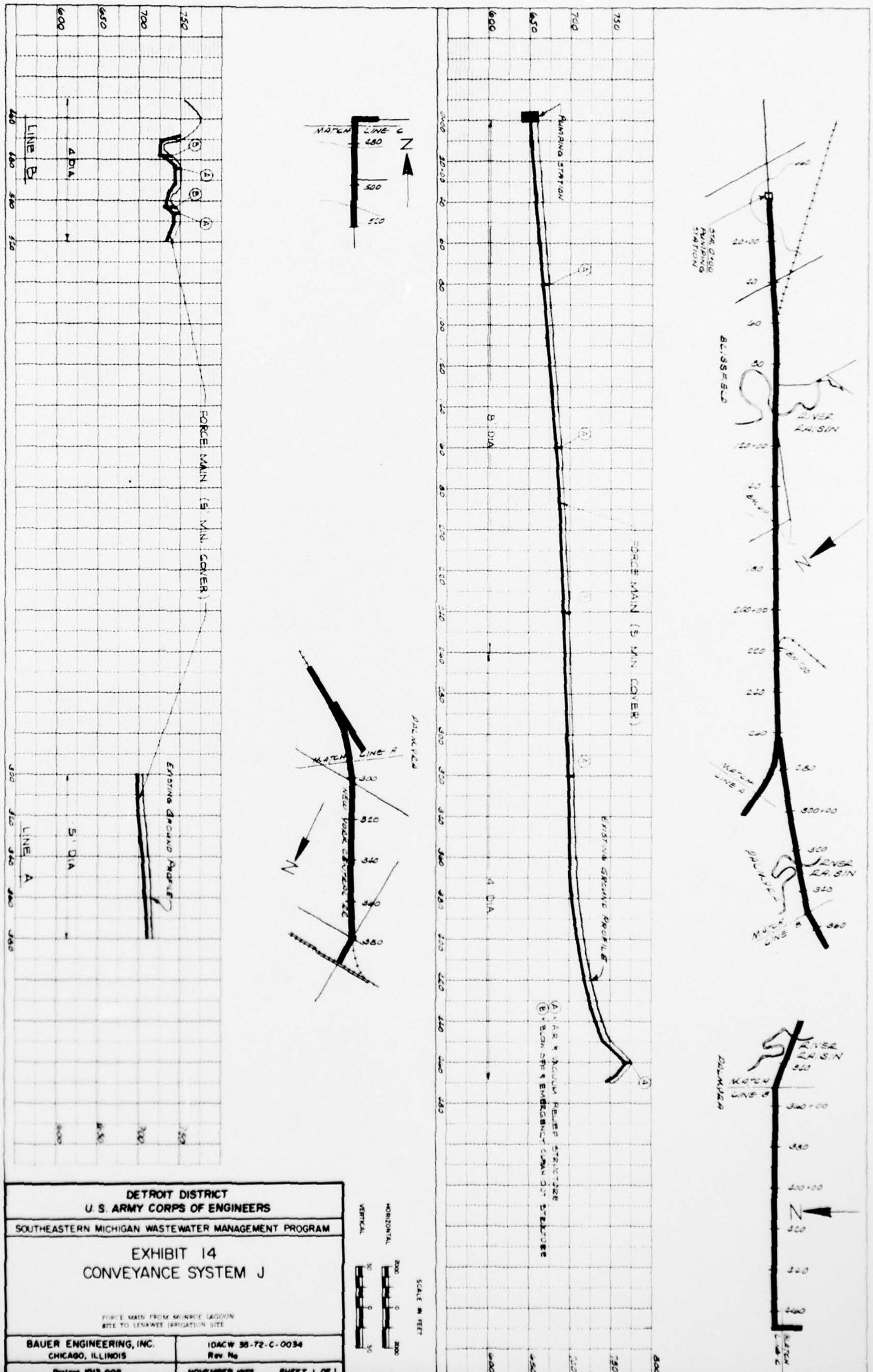
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 13
CONVEYANCE SYSTEM I

DACW 35-72-C-0034
Rev No

NOVEMBER 1972 SHEET 1 OF 1

SCALE IN FEET
HORIZONTAL 200 0 200
VERTICAL 50 0 50



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SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 14
CONVEYANCE SYSTEM J

FORCE MAIN FROM MONROE LAGOON
SITE TO LENAWEE IRRIGATION SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No
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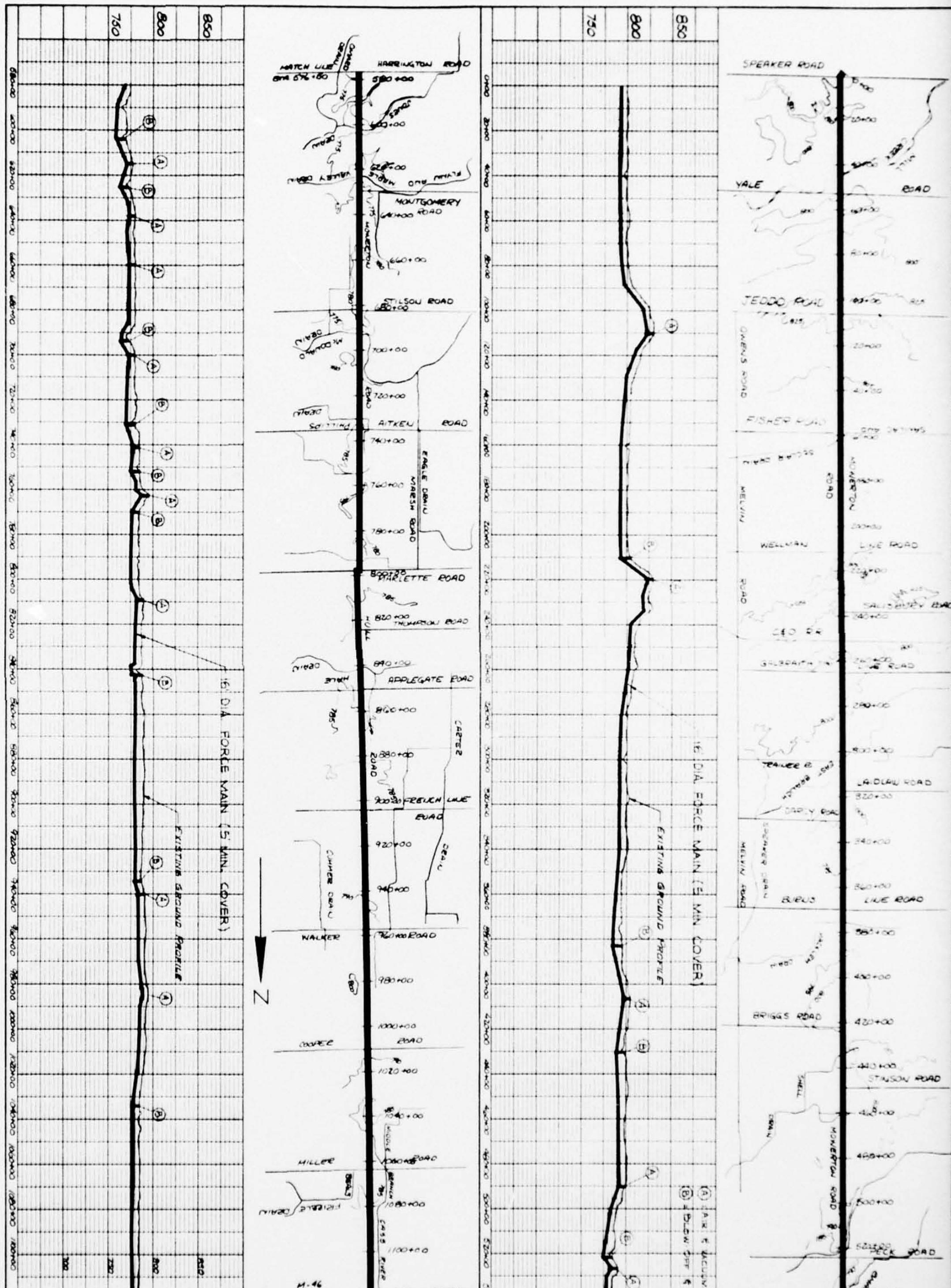


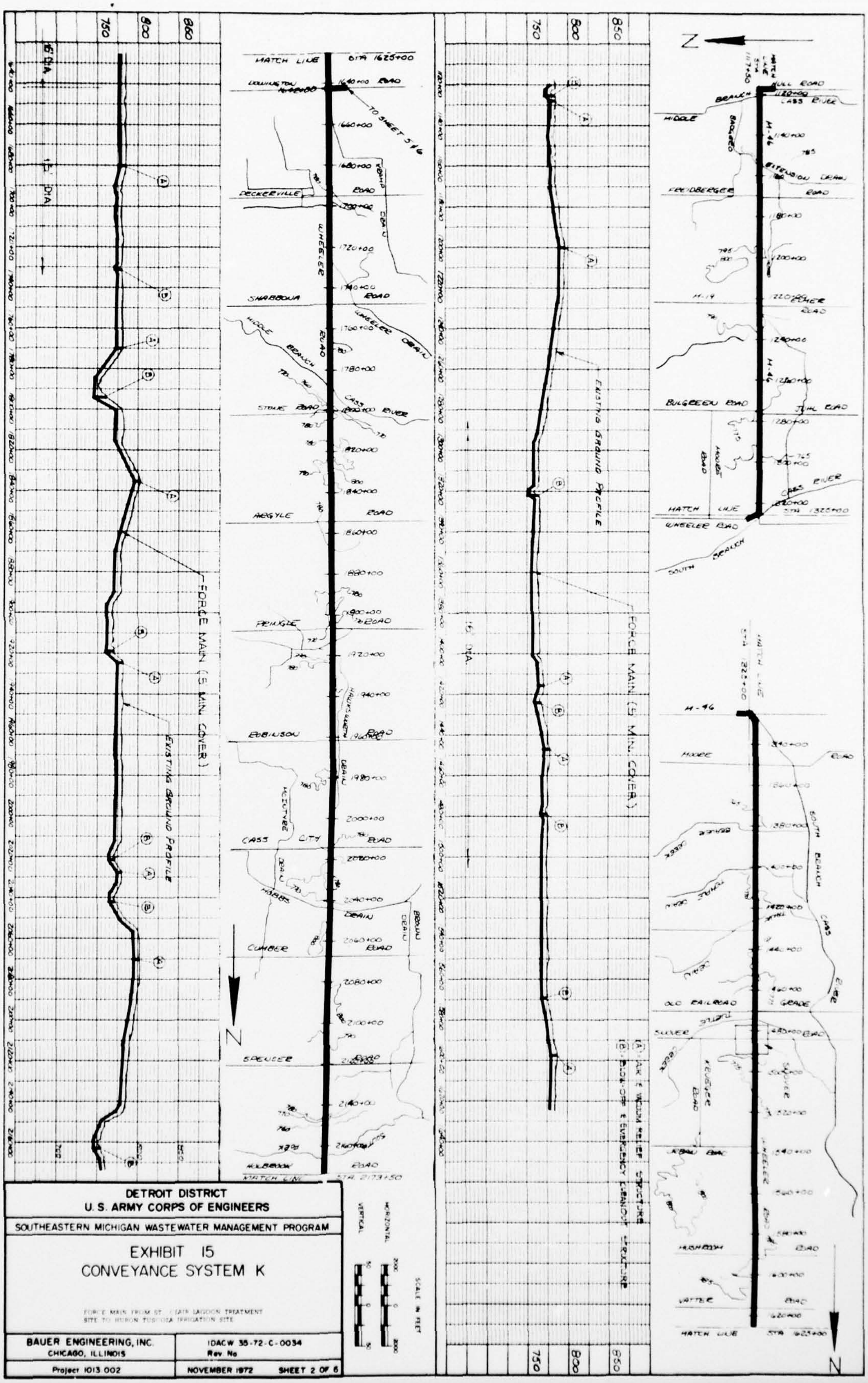
DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 15
CONVEYANCE SYSTEM K

FORCE MAIN FROM ST. CLAIR LAGOON TREATMENT SITE TO HURON TUSCOLA IRRIGATION SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No
Project 1013.002	NOVEMBER 1972 SHEET 1 OF 6



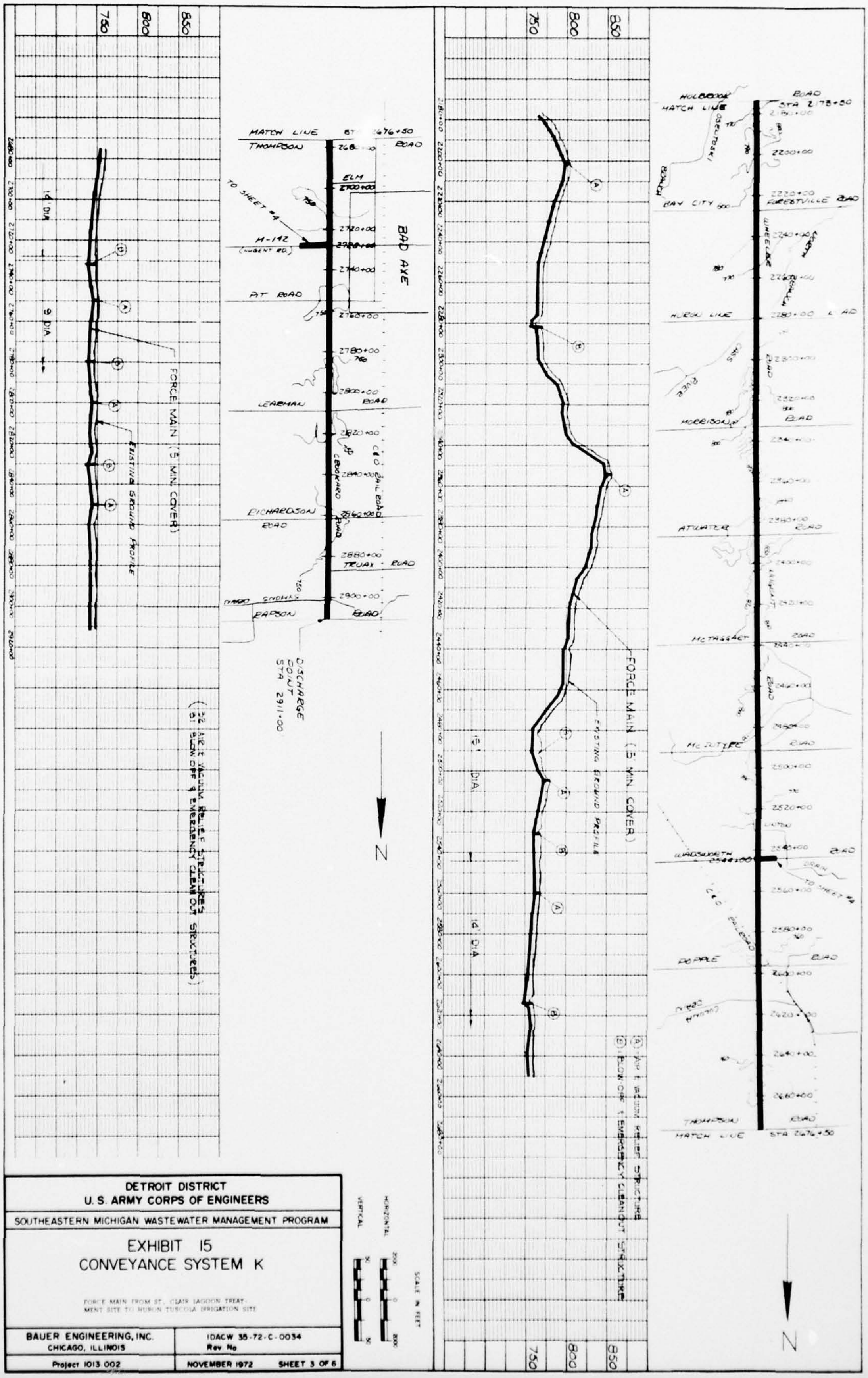
DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 15
CONVEYANCE SYSTEM K

FORCE MAIN FROM ST. CLAIR LAGOON TREATMENT SITE TO HURON-TUSCOLA IRRIGATION SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No
Project 1013.002	NOVEMBER 1972 SHEET 2 OF 6



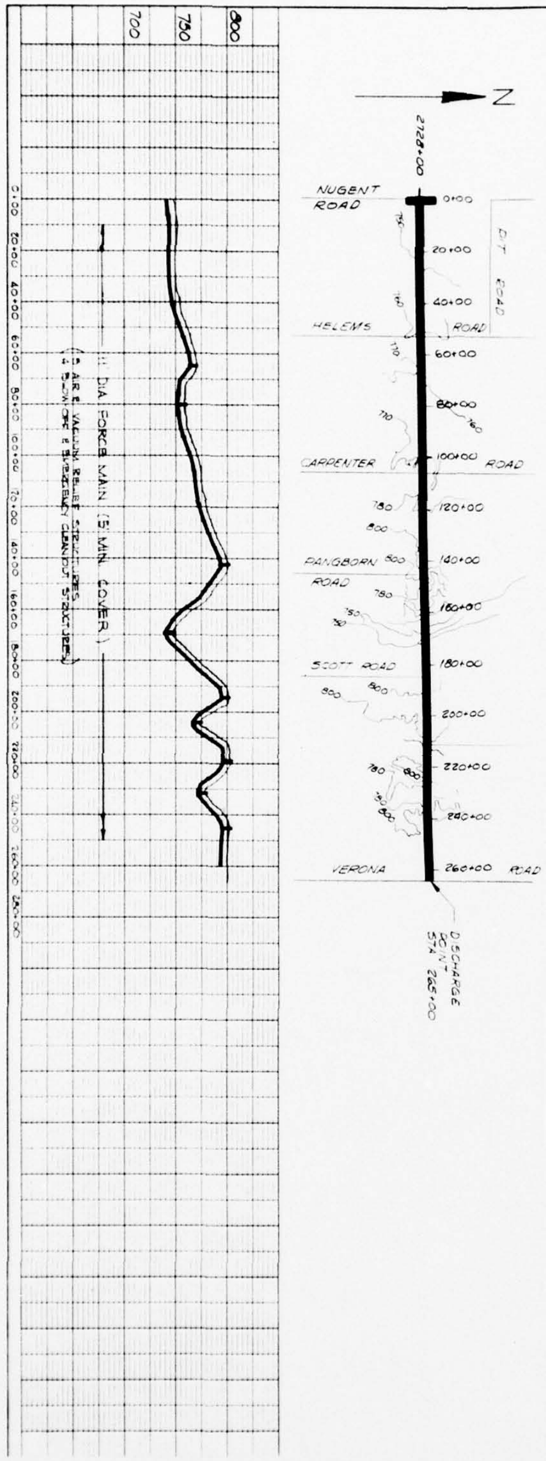
DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

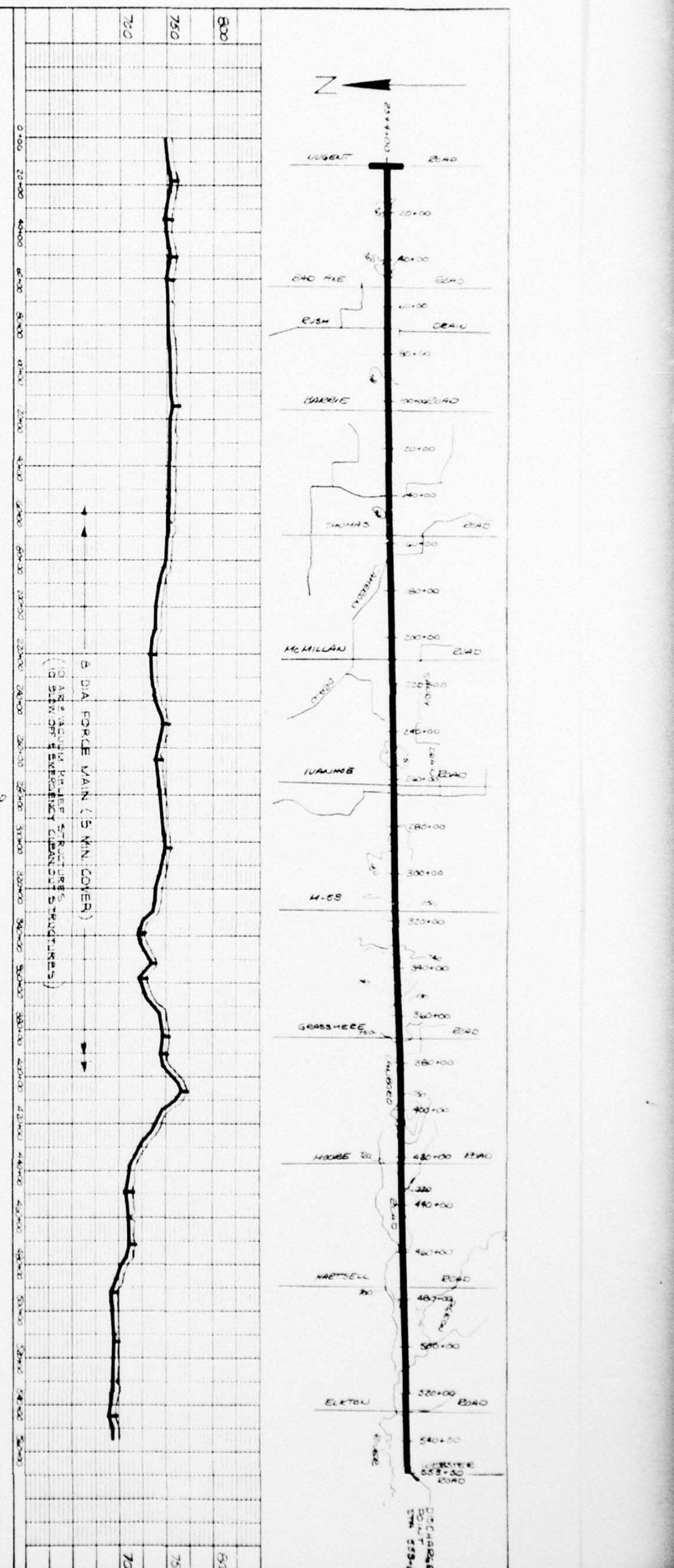
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 15
CONVEYANCE SYSTEM K

FORCE MAIN FROM ST. CLAIR LAGOON TREATMENT SITE TO HURON TUSCOLA IRRIGATION SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev No
Project 1013.002	NOVEMBER 1972 SHEET 3 OF 6





DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

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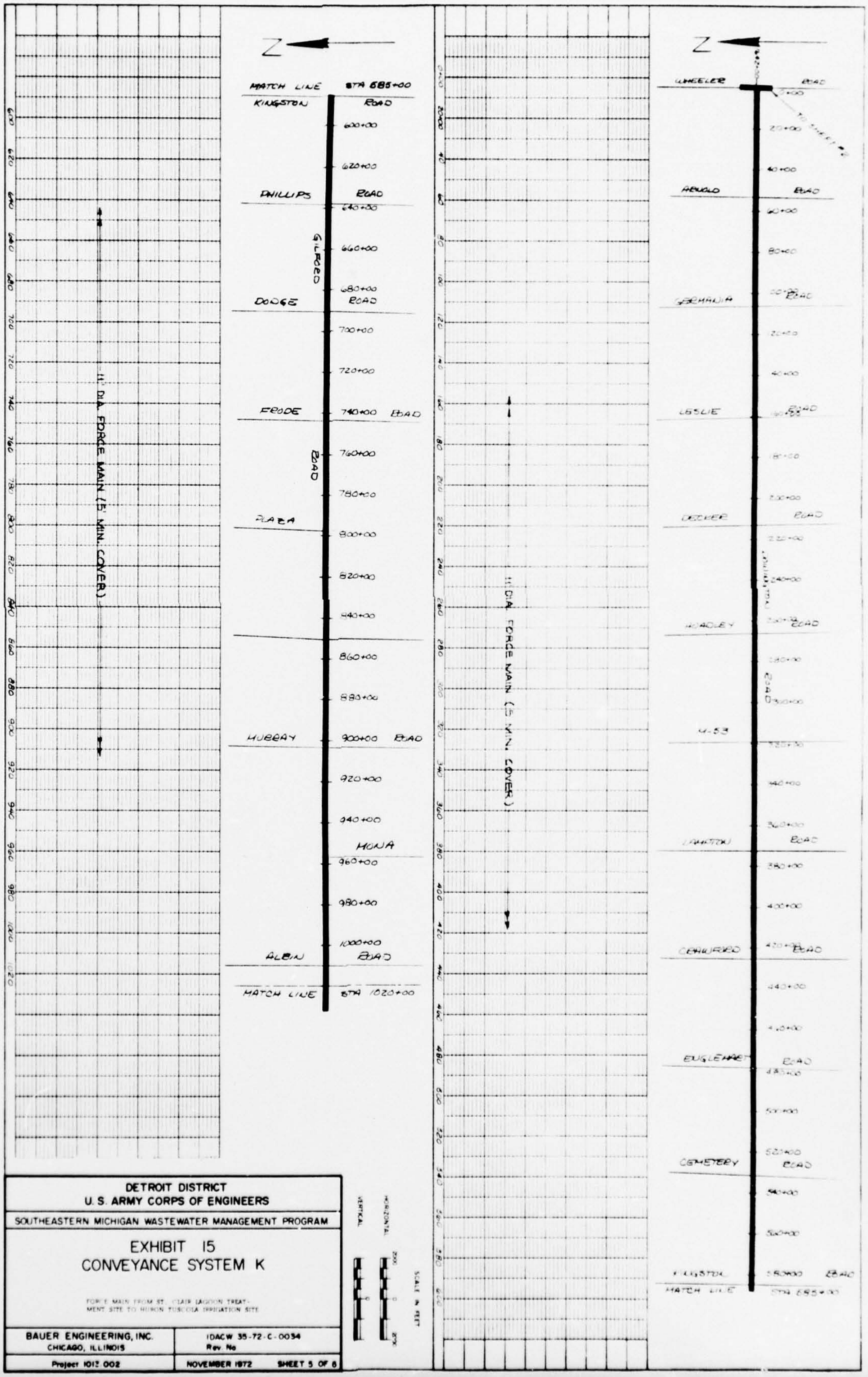
EXHIBIT 15
CONVEYANCE SYSTEM K

FORCE MAIN FROM ST. CLAIR LAGOON TREATMENT SITE TO HURON TUSCOLA IRRIGATION SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No
Project 1013.002	NOVEMBER 1972 SHEET 4 OF 6



DETROIT DISTRICT
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SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 15
CONVEYANCE SYSTEM K

FORCE MAIN FROM ST. CLAIR LAGOON TREATMENT SITE TO HURON TUSCOLA IRRIGATION SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No
Project 1012.002	NOVEMBER 1972 SHEET 5 OF 8

DETROIT DISTRICT
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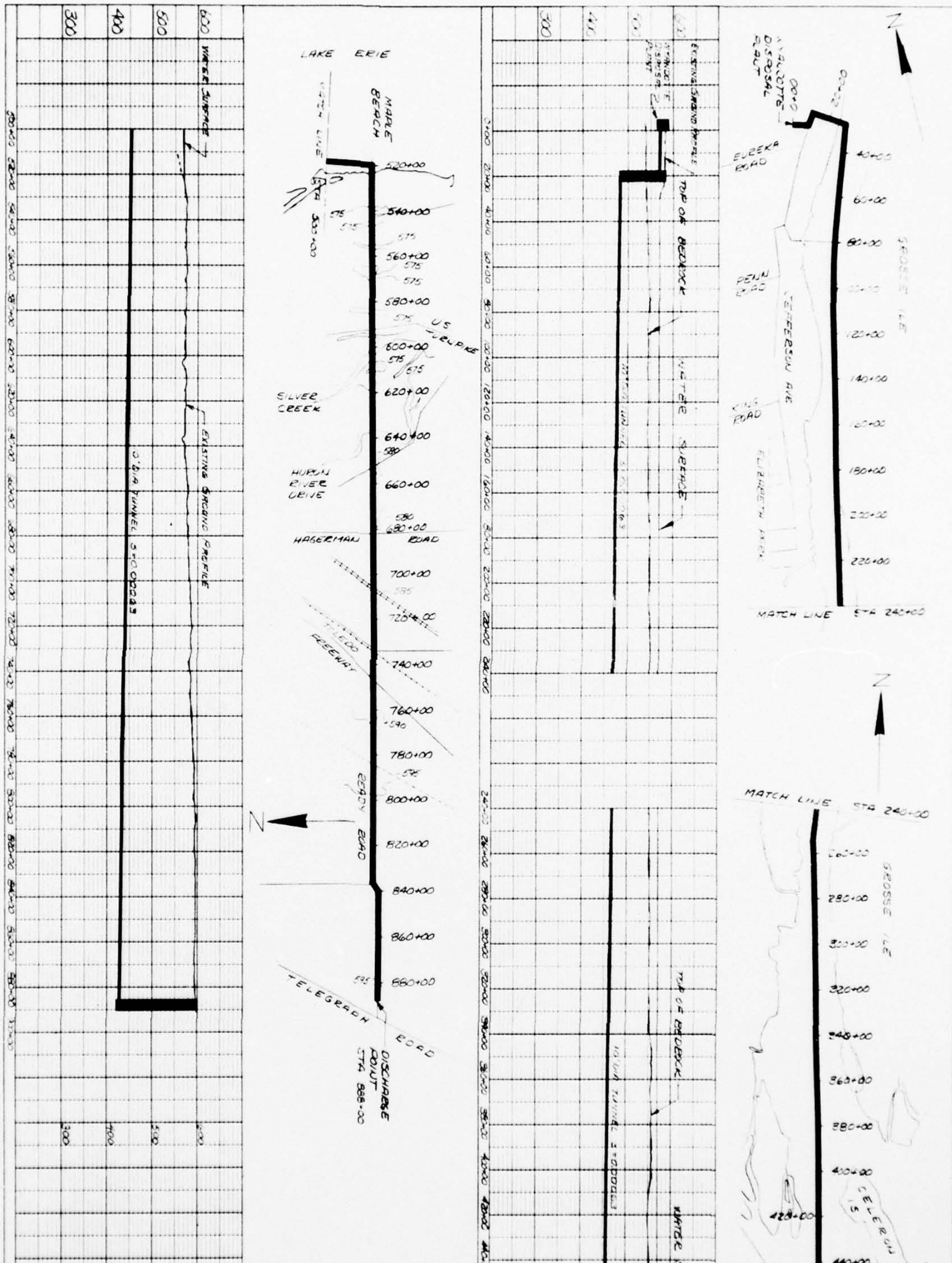
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 15
CONVEYANCE SYSTEM K

FORCE MAIN FROM ST. CLAIR LAGOON TREATMENT SITE TO HURON-TUSCOLA IRRIGATION SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	DACW 35-72-C-0034 Rev. No.
Project 1013.002	NOVEMBER 1972 SHEET 6 OF 6



DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 16
CONVEYANCE SYSTEM L

TUNNEL IN ROCK (OR INTERCEPTOR IN GLACIAL DRIFT) FROM WYANDOTTE TO TREATMENT PLANT AT THE MOUTH OF THE HURON RIVER

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev No
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SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 17
CONVEYANCE SYSTEM M

TUNNEL IN ROCK FOR INTERCEPTOR IN GLACIAL DRIFT FROM DETROIT TO MONROE LAGOON TREATMENT SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev No
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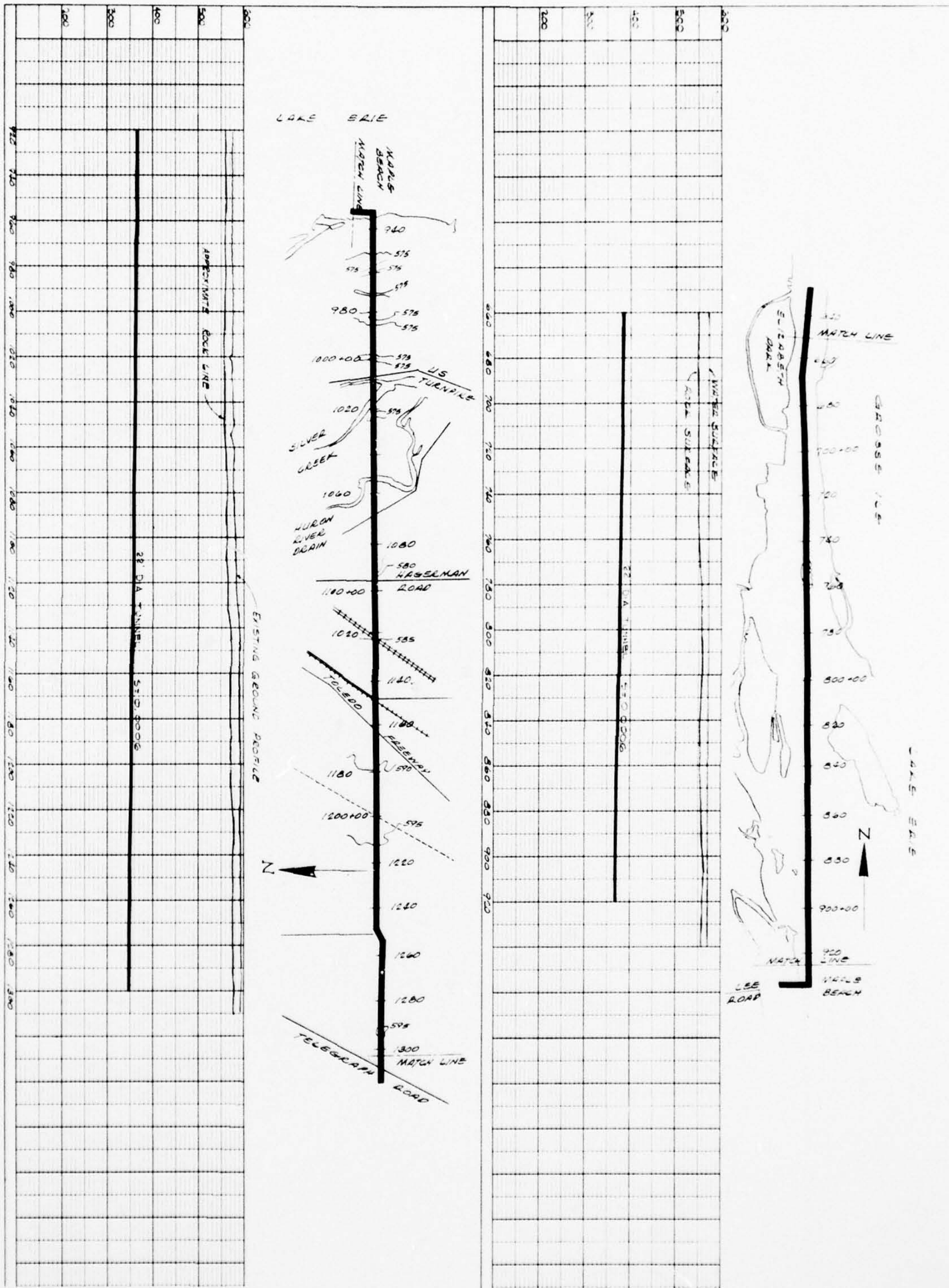
SCALE IN FEET

HORIZONTAL 2000 0 2000

VERTICAL 100 0 100



DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

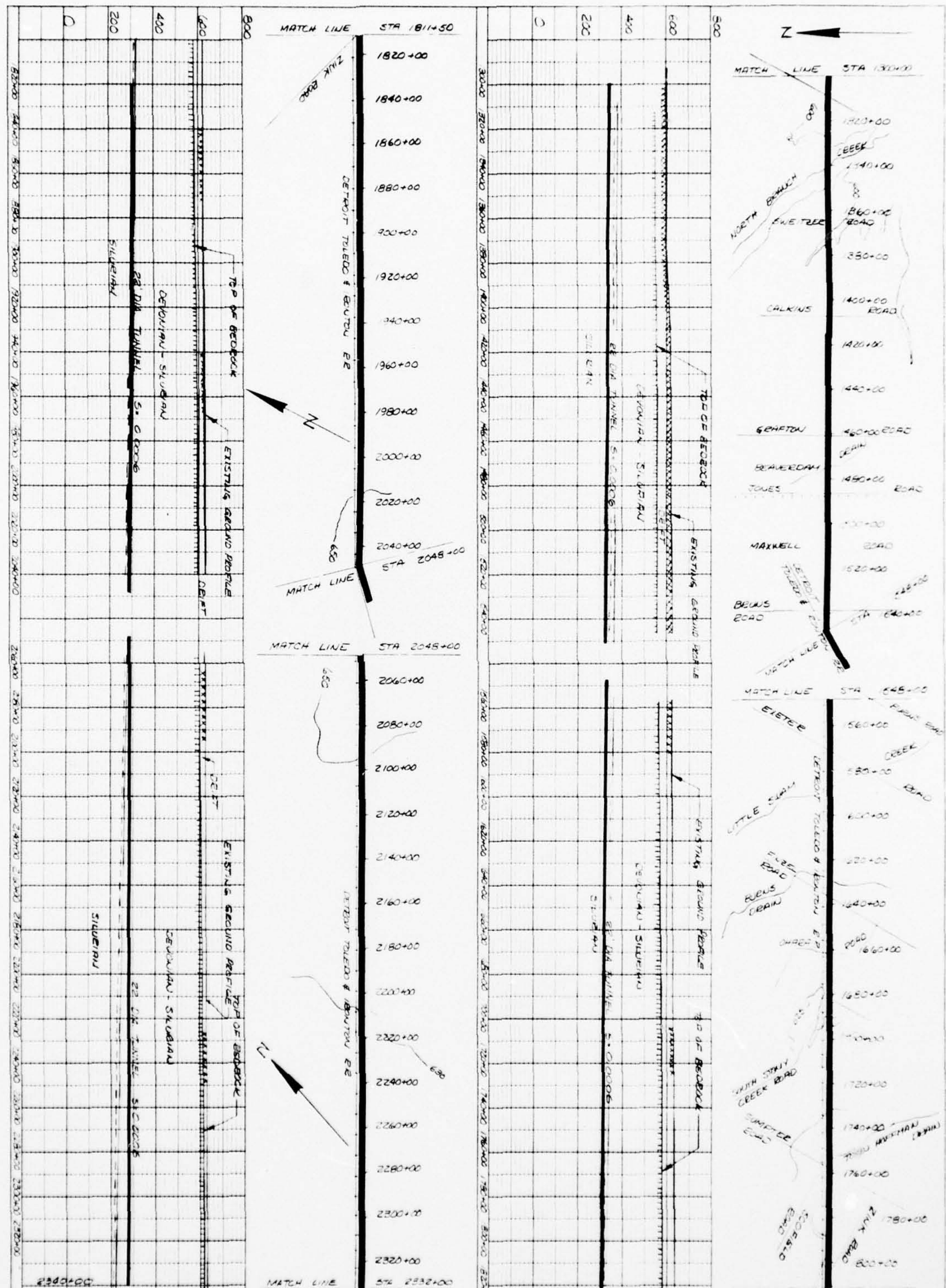
SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 17
CONVEYANCE SYSTEM M

TUNNEL IN ROCK FOR INTERCEPTOR IN GLACIAL DRIFT
FROM DETROIT TO MONROE LAGOON TREATMENT SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev No
Project 1013.002	NOVEMBER 1972 SHEET 2 OF 4

SCALE IN FEET
HORIZONTAL 2000 0 2000
VERTICAL 100 0 100



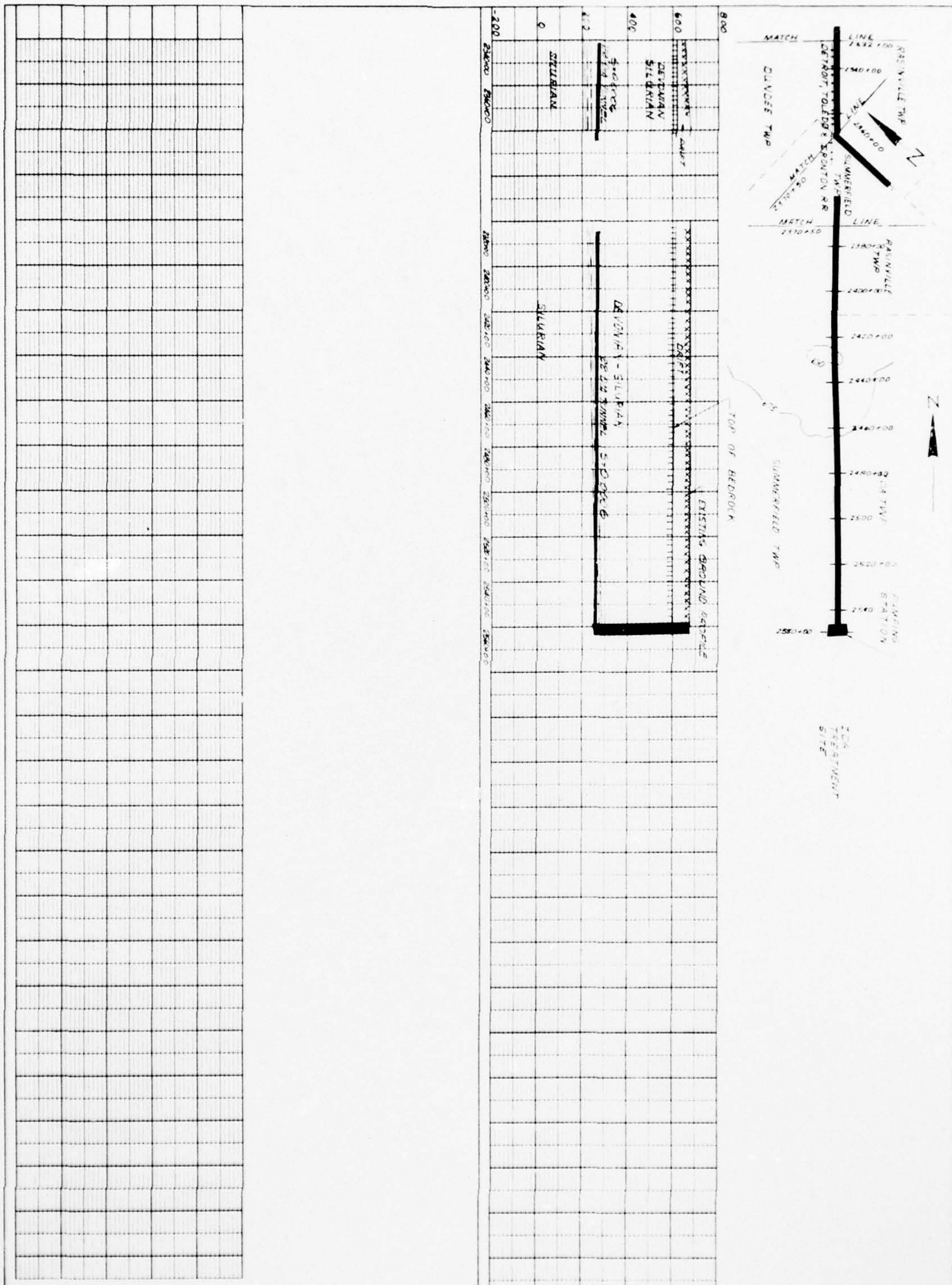
DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 17
CONVEYANCE SYSTEM M

TUNNEL IN ROCK OR INTERCEPTOR IN GLACIAL DRIFT
FROM DETROIT TO MONROE LAGOON TREATMENT SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No.
Project 1013.002	NOVEMBER 1972 SHEET 3 OF 4



SCALE IN FEET

HORIZONTAL 2000 0 2000

VERTICAL 200 0 200

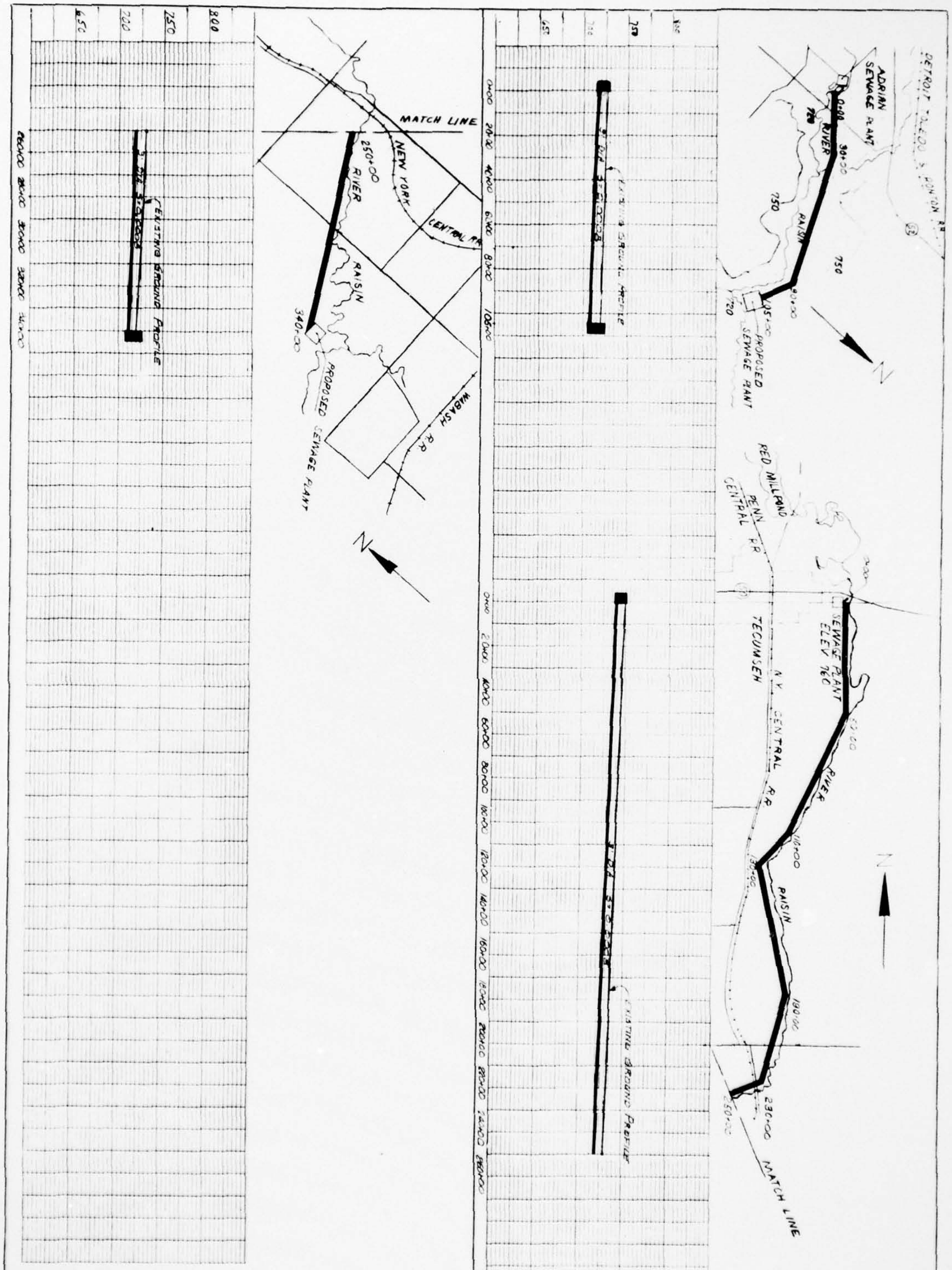
DETROIT DISTRICT
U. S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 17
CONVEYANCE SYSTEM M

TUNNEL IN ROCK (OR INTERCEPTOR IN GLACIAL DRIFT) FROM DETROIT TO MONROE LAGOON TREATMENT SITE

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev. No
Project 1013.002	NOVEMBER 1972 SHEET 4 OF 4



DETROIT DISTRICT
U.S. ARMY CORPS OF ENGINEERS

SOUTHEASTERN MICHIGAN WASTEWATER MANAGEMENT PROGRAM

EXHIBIT 18
CONVEYANCE SYSTEM N

INTERCEPTORS FROM TECUMSEH AND ADRIAN TO PROPOSED TREATMENT PLANT AT CONFLUENCE OF RIVER RAISIN AND SOUTH BRANCH OF RIVER RAISIN

SCALE IN FEET
HORIZONTAL 2000 0 8000
VERTICAL 50 0 50

BAUER ENGINEERING, INC. CHICAGO, ILLINOIS	IDACW 35-72-C-0034 Rev No
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END
8-27